Water-Supply and Irrigation Paper No. 94 Series M, General Hydrographic Investigations, 9

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

HYDROGRAPHIC MANUAL

OF THE

UNITED STATES GEOLOGICAL SURVEY

PREPARED BY

EDWARD C. MURPHY, JOHN C. HOYT, AND
GEORGE B. HOLLISTER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1904

PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

The publications of the United States Geological Survey consist of (1) Annual Reports; (2) Monographs; (3) Professional Papers; (4) Bulletins; (5) Mineral Resources; (6) Water-Supply and Irrigation Papers; (7) Topographic Atlas of United States, folios and separate sheets thereof; (8) Geologic Atlas of United States, folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

The Professional Papers, Bulletins, and Water-Supply papers treat of a variety of subjects, and the total number issued is large. They have therefore been classified into the following series: A, Economic geology; B, Descriptive geology; C, Systematic geology and paleontology; D, Petrography and mineralogy; E, Chemistry and physics; F, Geography; G, Miscellaneous; H, Forestry; I, Irrigation; J, Water storage; K, Pumping water; L, Quality of water; M, General Hydrographic investigations; N, Water power; O, Underground waters; P, Hydrographic progress reports.

The following Water-Supply Papers are out of stock, and can no longer be supplied: Nos. 1–16, 19, 20, 22, 29–34, 36, 39–40, 43, 46, 57–65, 75. Complete lists of papers relating to water supply and allied subjects follow. (PP=Professional Paper; B=Bulletin; WS=Water-Supply Paper.)

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WS 70. Geology and water resources of the Patrick and Goshen Hole quadrangles, Wyoming, by G. I. Adams. 1902. 50 pp., 11 pls.
WS 71. Irrigation systems of Texas, by T. U. Taylor. 1902. 137 pp., 9 pls.
WS 74. Water resources of the State of Colorado, by A. L. Fellows. 1902. 151 pp., 14 pls.
WS 87. Irrigation in India (second edition), by H. M. Wilson. 1903. 238 pp., 27 pls.
WS 93. Proceedings of first conference of engineers of the reclamation service, with accompanying papers, compiled by F. H. Newell, chief engineer. 1904. — pp.

The following papers also relate especially to irrigation: Irrigation in India, by H. M. Wilson, in Twelfth Annual, Pt. II; two papers on irrigation engineering, by H. M. Wilson, in Thirteenth Annual, Pt. III.

SERIES J—WATER STORAGE.

WS 33. Storage of water on Gila River, Arizona, by J. B. Lippincott. 1900. 98 pp., 33 pls.
WS 40. The Austin dam, by Thomas U. Taylor. 1900. 51 pp., 16 pls.
WS 45. Water storage on Cache Creek, California, by A. E. Chandler. 1901. 48 pp., 10 pls.
WS 46. Physical characteristics of Kern River, California, by F. H. Olmsted, and Reconnaissance of Yuba River, California, by Marsden Manson. 1901. 57 pp., 8 pls.
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WS 68. Water storage in Truckee Basin, California-Nevada, by L. H. Taylor. 1902. 90 pp., 8 pls.
WS 73. Water storage on Salt River, Arizona, by A. P. Davis. 1902. 54 pp., 25 pls.
WS 86. Storage reservoirs on Stony Creek, California, by Burt Cole. 1903. 62 pp., 16 pls.
WS 89. Water resources of the Salinas Valley, California, by Homer Hamlin. 1904. — pp., 12 pls.
WS 93. Proceedings of first conference of engineers of the reclamation service, with accompanying papers, compiled by F. H. Newell, chief engineer. 1904. — pp.

The following paper also should be noted under this heading: Reservoirs for irrigation, by J. D. Schuyler, in Eighteenth Annual, Pt. IV.

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
HYDROGRAPHIC BRANCH,
Washington, D. C., February 1, 1904.

SIR: I have the honor to transmit herewith a manuscript entitled "Hydrographic Manual of the United States Geological Survey," and to ask that it be published as a water-supply and irrigation paper.

It gives instructions for field and office work relating to gaging of streams by the use of current meters. Instructions relative to gaging streams by the use of weirs and dams will be embodied in a future edition of this manual.

This manuscript has been prepared by a committee composed of Messrs. Edward C. Murphy, John C. Hoyt, and George B. Hollister. They have endeavored to bring together all available information in regard to the methods of gaging streams which have been developed by the engineers and hydrographers of the United States Geological Survey, and in so doing have, as far as possible, consulted these men.

The publication is intended mainly for those engaged in hydrographic investigations for the Geological Survey. It is believed, however, that engineers and others not connected with the Government service who are interested in hydraulic problems will find it of much assistance. It is hoped, also, that teachers of civil engineering will make use of it in their courses of instruction, so that young men who enter this branch of the Government service may be familiar with the stream-gaging methods herein set forth.

Very respectfully,

F. H. NEWELL,
Chief Engineer.

HON. CHARLES D. WALCOTT,
Director United States Geological Survey.

HYDROGRAPHIC MANUAL OF THE UNITED STATES GEOLOGICAL SURVEY.

Prepared by E. C. Murphy, J. C. Hoyt, and G. B. Hollister.

INTRODUCTION.

The problem presented to the United States Geological Survey when it started to make systematic stream measurements throughout the United States, was to obtain with a small sum of money a large amount of information concerning the principal rivers of the country. In order that the data obtained should be of most value it was decided that both the total yearly flow of the streams and the seasonal distribution should be ascertained. Methods of procuring data of this broad nature had not at that time been developed, and many engineers considered the task impossible. However, on careful analysis of the conditions, it was found that the data could be obtained, and that in order to procure them two factors should be determined—first, the stage of the stream from day to day; second, the discharge corresponding to the various stages. The hydrographers and engineers engaged in the work have spent much time in devising means for determining these factors, and as a result well-defined methods have now been developed.

As literature in regard to these methods is either widely scattered or entirely lacking, this manual has been prepared. Its object is two-fold—first, to act as a guide for the engineers and hydrographers employed by the Geological Survey; second, to give the engineering public the benefit of these studies, in order that the methods of determining the facts as well as the data obtained may be more widely and fully understood.

The work of gaging streams would be greatly simplified if a single rule or method could be given which, when carefully followed, would in all cases give the most satisfactory results, but owing to the great diversity of conditions in different sections of the country it has been found that no such rule can be given; therefore, an effort has been made to state simply the methods of performing the various operations with the conditions to which each is applicable.

During the last few years the practice of gaging streams by weirs and dams has come into use to a considerable extent in the northeastern part of the United States, but the treatment of this method has been left for a future edition of this manual.

It is requested that those using this manual will make any suggestions that they think will be of value, in order that such suggestions may be incorporated in future editions.

Acknowledgments.—Thanks are due to many engineers and hydrographers for aid in the preparation of this manual. In this connection special acknowledgments are made to Messrs. N. C. Grover, R. E. Horton, M. R. Hall, A. L. Fellows, M. C. Hinderlider, John E. Field, B. M. Hall, O. V. P. Stout, T. A. Noble, G. L. Swendsen, and F. W. Hanna.

FIELD OPERATIONS.

SELECTION OF GAGING STATIONS.

Classes and location of stations.—Gaging stations may be divided into two classes, temporary and permanent; the former are maintained for one season, the latter for a series of years. Permanent stations should be selected only after a very thorough reconnaissance, so that the best results for the river and section investigated may be obtained, without breaks in the record. In the eastern part of the United States data are wanted mainly for water-supply and power purposes; in the central part, for water-supply and sanitary purposes; and in the West for irrigation and domestic purposes. At some stations in each section of the country information is desired for general statistical uses. The sanitary work carried on in connection with stream-gaging work consists mainly in determining the degree of dilution of sewage in the streams, and this work is done to some extent in the eastern as well as in the central part. Each station should be located so as to secure the requisite data with the proper degree of accuracy and at reasonable cost. For power purposes data concerning low and ordinary stages are more valuable than data for higher stages; hence low-water conditions should govern the selection of stations. Where the information is to be used mainly to determine the feasibility of storage projects, a station should be so located that high as well as low water can be measured with accuracy. Where the information sought is for irrigation purposes stations should preferably be established above all diversions, at points reached by telephone, or at such points as will aid in the distribution of the water.

Favorable conditions for current-meter gaging stations.—The channel at a gaging station should be as nearly straight as possible for from 200 to 500 feet above and below the station, the distance depending on the size of the stream, and there should be few if any obstructions.

The bed should be fairly permanent, regular in shape, and have few projections of more than 4 inches above its general coutour. There should be no sudden change in velocity, and the velocity should not be less than one-half foot per second in more than 15 per cent of the cross section. The station should be far enough above the junction with other streams to be free from the influence of backwater and should be beyond the influence of dams. The banks should be fairly high and not liable to overflow, except during high floods. It should be easily accessible and there should be a reliable gage reader located within a quarter of a mile of the gage.

Unfavorable conditions for current-meter gaging stations.—A gaging station should not be established where a reliable gage reader can not be secured; at a bend in a stream; at a bridge of short spans where drift collects or where the sides of the piers are not approximately parallel to the stream; at high trestle and railway deck bridges, on account of danger; at covered bridges, unless provided with numerous windows; near the mouth of a river having little fall; within the backwater above a dam; nor within such a distance below a dam that the shifting of currents in the stream channel, caused by the flow or cessation of flow over the spillway or through the turbines, has not disappeared. A sandy, shifting section is to be avoided if possible, as a rating curve for such a station is applicable for only a limited time. Sand beds or bars adjacent to the gaging section, which by shifting or scouring might change the velocity in the section, should be avoided.

It frequently happens that during the higher stages good results can be obtained from a bridge, but during the lower stages the flow becomes too sluggish or the depth too shallow to permit accurate measurement. Very often the best results can be obtained by wading, or by the use of a boat, at places not far from the station.

Whenever possible a station should be situated a short distance above rapids or a place of permanent bed. The rapids themselves seldom offer a good location, for the stream there is likely to be very rough and shallow and the velocity high. If the station is located too far above the rapids the stream is likely to be sluggish at low stages. The scouring or filling above the rapids has little effect on the station rating curve.

CLASSIFICATION AND EQUIPMENT OF GAGING STATIONS.

Kinds of stations and items of equipment.—Current-meter gaging stations may be divided, according to equipment, into bridge, cable, and boat stations. The equipment of a station consists of a bridge, or a cable and car, or a boat, as the case may be, from which measurements are made; a tag line and tags or marks on the bridge indicating the points at which the meter is lowered and soundings taken; a gage

for reading the surface fluctuations; bench marks for fixing the elevation of the zero of the gage; and when high velocities are to be measured a stay line for keeping the meter in place (see fig. 2).

Bridge stations.—A bridge station is preferable to either a cable or a boat station, if the conditions are good, on account of greater accessibility, lower cost of maintenance, and ease and rapidity with which the measurements may be made. The measurements made at a bridge are not, as a rule, as accurate as those made from a cable or boat, for conditions are not likely to be so favorable.

Cable stations—(*See Pl. I, A*).—In case a bridge station is not available and the span is less than 500 feet, a cable can be stretched across the stream at right angles to the current at a point where conditions are satisfactory, and measurements made from a box operated on this cable. The cable may be suspended from a tree on each side, if trees are available, or from posts, as shown in fig. 1. The height of the posts will depend on the height of the banks and the change in

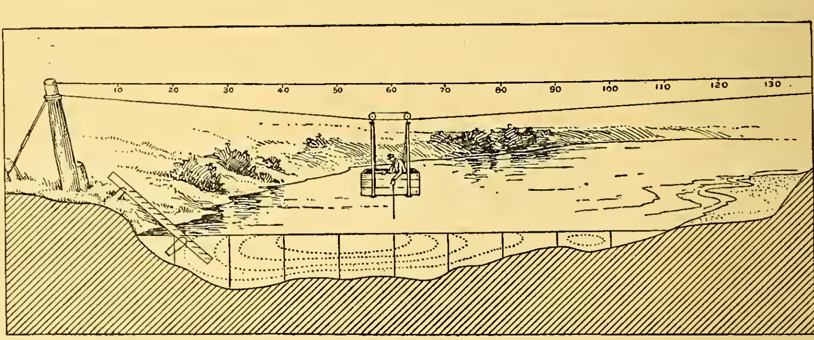
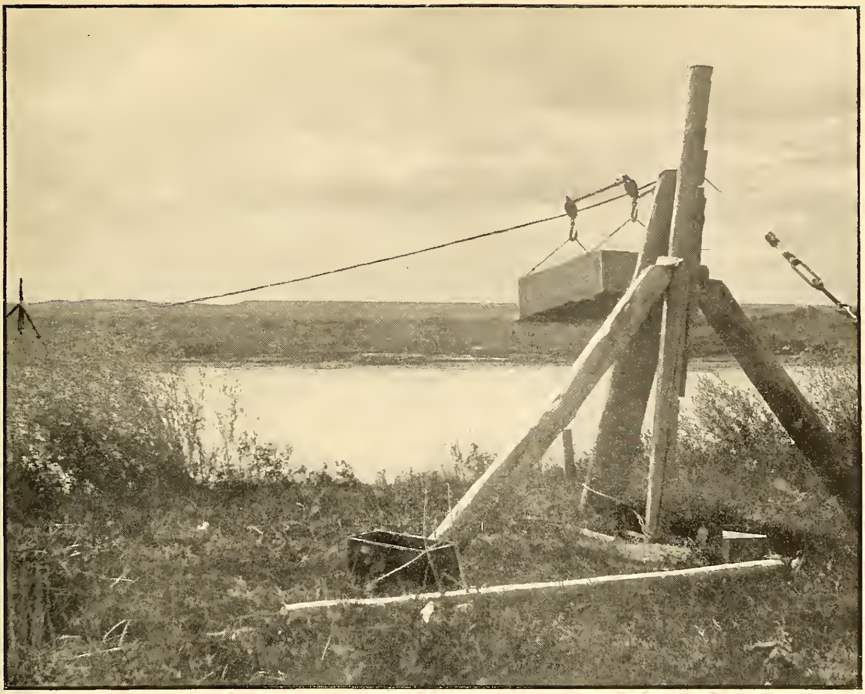


FIG. 1.—Cable station, car, gage, etc.

river stage. The cable should always be so high above the stream that the car will be several feet above water level in the middle of the span when the stream is at flood stages. Each end of the cable, after passing over the posts, is fastened to a timber or heavy iron rail called a "dead man," at least 4 to 6 feet long and 6 to 10 inches in diameter, one end of which is buried 3 or more feet in the ground. Near one end, between the support and the dead man, a turnbuckle should be inserted for tightening the cable when the sag becomes too great for easily moving the car. The equipment for a cable station includes the following items for spans of from 100 to 300 feet: A five-eighths inch galvanized-wire cable; eight Crosby clips, costing about 40 cents each; two 6-inch galvanized-iron pulleys; one turnbuckle (right and left hand thread), with 2-foot capacity, and one gaging car or box 3 by 4 feet by 1 foot deep, made of common lumber and painted. The turnbuckle must generally be made to order, of wrought iron, and will cost from $3 to $5. Above the main cable a wire (preferably common barbed wire) is stretched, to which are attached tin



A. CABLE POST AND CAR.

B. BOAT STATION.

or galvanized-iron tags, marking the intervals at which measurements are made. The tags should be of different shapes—round, oval, or rectangular—with suitable notches to indicate their distance from the initial point, or should have numbers clearly marked upon them, so that no confusion can arise as to the units, tenths, etc.

For spans of less than 100 feet, a one-half inch cable anchored as above described and supported on 10 by 12 timbers set 4 feet in the

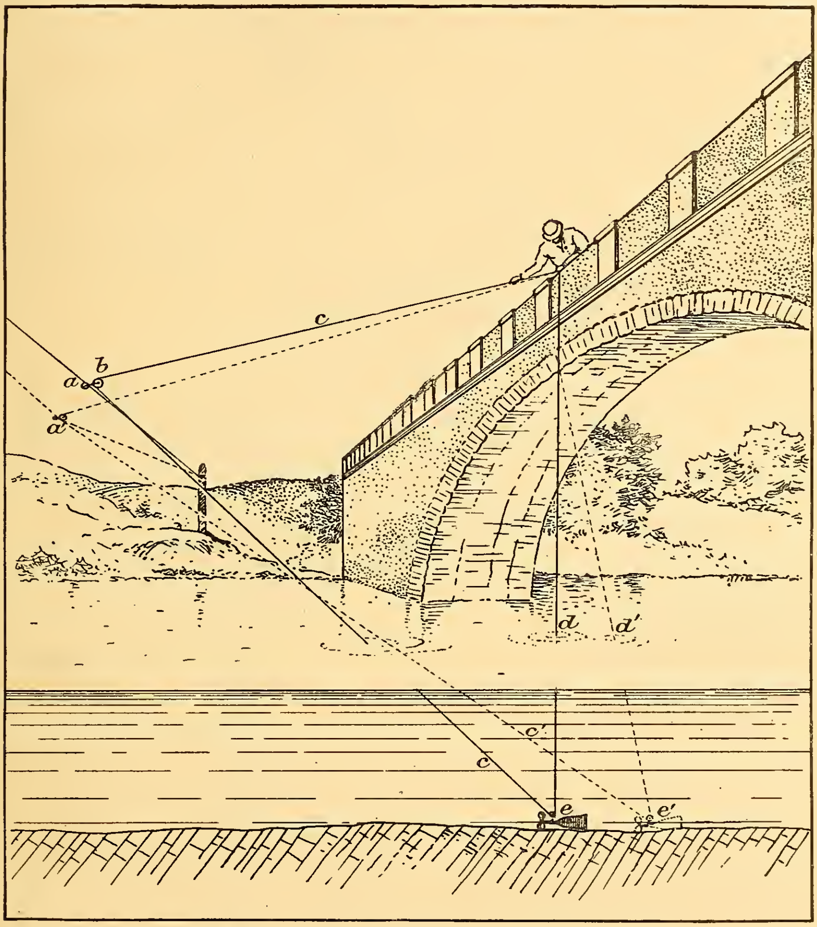


FIG. 2.—Method of manipulating stay line from small cable.

ground will serve. The cable may be attached directly to an iron bolt, 1 inch in diameter, set through the post near its upper end. If two or three bolt holes are made through the post they may be used to aid in adjusting sag in the cable, the bolt being shifted from one hole to another, if necessary. The posts should incline back from the water somewhat, so that they may not be liable to bend under stress.

Boat stations.—Where a bridge is not available, and the width of the

stream is too great for the use of a cable and the depth too great for wading, measurements are made from a boat. For description of measurements by wading see page 21. Two small cables, three-eighths inch in diameter, one to be used as a tag line, the other as a stay line, as shown in Pl. I, *B*, should be used. The meter should be operated from the upstream end of the boat, and should be held several feet away from it.

If the timber that carries the meter and projects from the boat is marked in feet and tenths, it will be found helpful in measuring depths and in lowering the meter to any desired depth. To lower the center of the meter to a depth of 3 feet, first lower it until the center is at the surface, then grasp the line carrying the meter at a foot mark and let the meter descend until the hand has moved over three of the foot marks; the center will then be 3 feet below the surface.

In measuring from a boat two assistants will ordinarily be necessary, one to operate the boat and another the meter while the hydrographer keeps the time and makes the record. A rod marked to feet and tenths is convenient for making soundings from a boat.

GAGES.

Two forms of gages for measuring surface fluctuations are in use—either a timber, vertical or inclined, fastened rigidly to the bank or to some permanent object, as a tree, pile, or bridge pier; or a chain gage attached to some permanent part of a bridge.

A timber gage should not be smaller than 4 by 4 inches and should be marked to feet and tenths of feet vertical depth. Occasionally a tree growing over the water will furnish a good support for a gage; a bridge pier is usually not a good support because of the suction and consequent lowering of the surface, and because it is usually too far from the shore to enable the gage to be easily read.

A vertical gage in two sections may often be used to advantage. The upper part should be in some protected position on the bank for use at high water only; the lower part, for low-water stages, should be of such length that it will be submerged during high stages.

The gage markings should be as permanent as possible. U-shaped galvanized iron staples make good marks. When paint is used the divisions should be indicated by V-shaped grooves one-fourth inch wide and one-eighth inch deep. These grooves should be painted black and the surface of the rod painted white.

In order that minus readings may never be necessary, the "0" of the gage should be 3 feet below lowest known low water, or, in permanent channels, level with the bottom in the deepest place.

It is often possible to use an inclined timber gage where a vertical one can not be used on account of the danger of its being destroyed.

An inclined timber gage should be placed where it is least exposed to drift, and where the water is quiet, so that it can be accurately read; it should have its lower end always under water and be bolted or spiked to posts firmly set in the bank. It should be marked to read to vertical feet and tenths direct, and for this purpose an engineer's level or carpenter's square and level are necessary to determine what distance along the rod corresponds to a foot vertically. It is usually better to

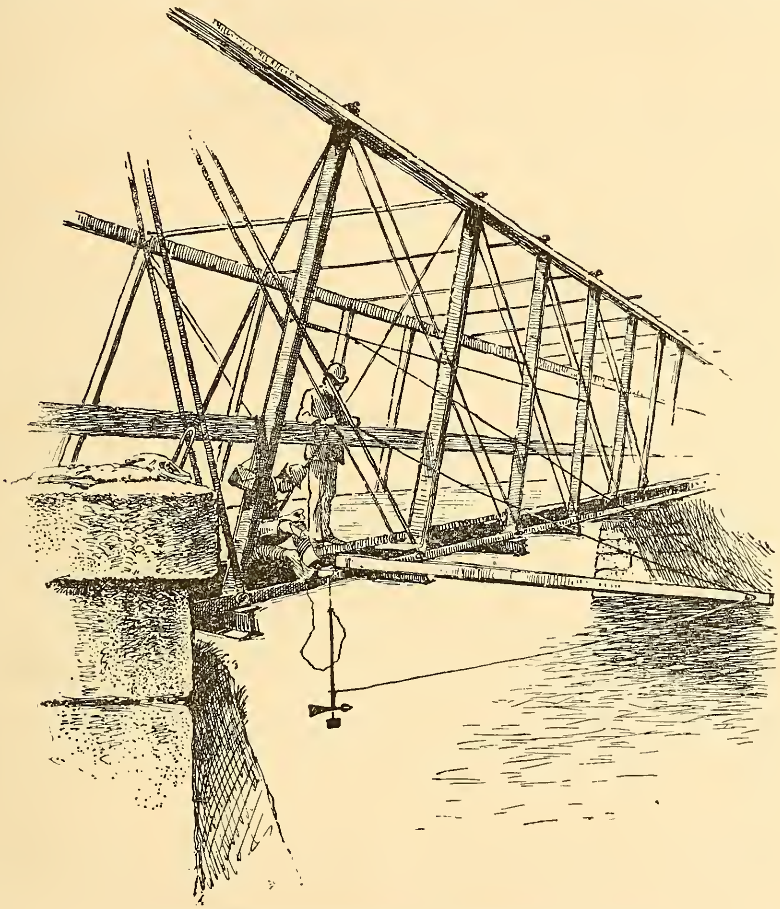


Fig. 3—Method of attaching stay line to meter by use of pole.

put the rod in position, place a few of the foot marks on it, remove the rod and complete the markings, and then permanently fasten it; or the slope of the rod may be taken, and a corresponding scale marked upon a board of the proper width may be afterwards firmly fastened to the gage timber.

The U. S. G. S. standard chain gage, shown in fig. 4, is to be used where ice, logs, and drift will destroy a timber gage, or where, for any

cause, a timber gage can not be used. It must always be inclosed in a box with a down-spout to protect the weight, and the box must be kept locked. The length of the chain will vary somewhat, and the difference in length must be determined at each visit of the hydrographer, and allowed for when a discharge measurement is made. For checking the gage without a level there should be a bench mark on the ironwork of the bridge, from which the elevation of the water surface can be read with a steel tape and weight. On the underside of the gage-box cover should be marked the length of the chain when the gage was

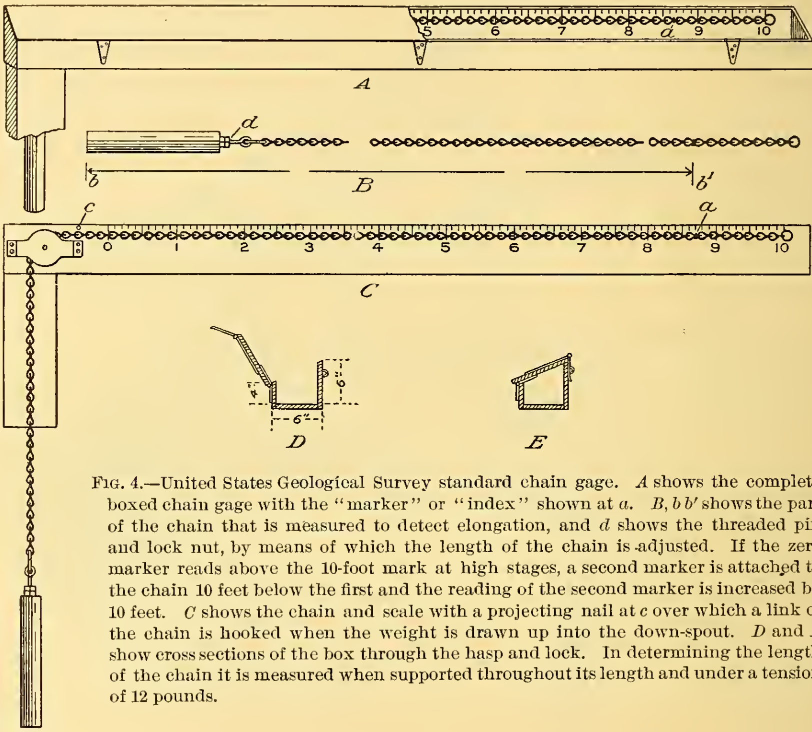


FIG. 4.—United States Geological Survey standard chain gage. *A* shows the complete boxed chain gage with the "marker" or "index" shown at *a*. *B*, *b b'* shows the part of the chain that is measured to detect elongation, and *d* shows the threaded pin and lock nut, by means of which the length of the chain is adjusted. If the zero marker reads above the 10-foot mark at high stages, a second marker is attached to the chain 10 feet below the first and the reading of the second marker is increased by 10 feet. *C* shows the chain and scale with a projecting nail at *c* over which a link of the chain is hooked when the weight is drawn up into the down-spout. *D* and *E* show cross sections of the box through the hasp and lock. In determining the length of the chain it is measured when supported throughout its length and under a tension of 12 pounds.

installed and the elevation of the "0" of the gage. The data for checking the gage will then always be at hand for testing the correctness of the gage reading. For example, suppose the surface of the water is 20 feet below the bench mark when the gage reads "0" and the chain length is 20.40 feet. At the next visit the gage reads 1.27 feet, and the distance from the water to the bench mark is 18.75, then the chain has stretched two-hundredths of a foot, unless the center of the gage pulley has changed. By measurement the chain is found to be 20.42 feet in length and should be shortened two-hundredths of a foot by the adjusting device at the upper end of the weight. The bench mark on the bridge should occasionally be checked with a level.

All the hardware for the gage can be obtained at the Washington office, including the lock. It is necessary that the standard United States Geological Survey lock be used, so that the inspector can read the gage when he visits the station.

At stations where the importance of the work calls for a greater degree of accuracy than is given by reading the gage to half-tenths, a low-water gage can be used, marked to the quarters of tenths, and read to the nearest quarter of a tenth, or marked to one-hundredths of a foot, and read to hundredths of a foot, the marking and reading to be determined by the district hydrographer.

A scale 2 or 3 feet in length and marked to hundredths of a foot can be used in some cases to advantage for measuring down to the water's surface from a well-defined point conveniently located.

BENCH MARKS.

There should be at least two bench marks at each gaging station; one preferably a copper plug set in a rock above high water, where it will not be disturbed, the other a point on the ironwork of the bridge from which the elevation of the surface of the water can be read with a steel tape. In sand and alluvial river bottoms where rock can not be found the United States Geological Survey iron post can be used. A surveyor's bench mark is sometimes found on a bridge, and it is therefore necessary to mark the bench mark with "U. S. G. S." so that it can be distinguished from other marks of a similar kind. A cross cut on a ledge of rock or bridge abutment is sometimes used; a spike in a tree is only a temporary mark. Bench marks should be so placed that they can be easily found, and a full description forwarded to the Washington office, with the "description of station."

STAY LINES.

In a swift current the meter will be carried downstream in spite of any weight of lead that can be operated by one man. To keep it directly underneath the point of measurement a stay line is used. This stay line may be a one-fourth-inch steel galvanized cable, fastened to posts on the banks, carrying a small pulley. The meter is operated from this stay line, as shown in fig. 2 (page 13).

A pole projecting upstream from the bridge is sometimes used in place of a stay line for keeping the meter at the proper depth. The meter is operated from this pole, as shown in fig. 3 (page 15). It is, however, difficult, even with these devices, to keep the meter at the desired depth, so that it is usually better to measure the velocity 1 foot below the surface and apply a coefficient to obtain the mean velocity. These devices can be used to advantage in obtaining characteristic vertical velocity curves from which this coefficient may be derived.

MEASUREMENTS OF DEPTH.

Factors for computing discharge.—The volume of water flowing in a stream in one second, or the discharge, is a product of two factors—mean velocity per second and cross section. The cross section is the product of two factors—mean depth and width. If the cross section were a rectangle and the velocity constant in all parts of it the measurement of discharge would be a simple matter, but the cross section of a natural stream is usually irregular in shape, and the velocity varies from the bank to the center and from the bottom to the surface. Considerable judgment is necessary, therefore, in selecting points in the cross section where depth and velocity should be measured, and in determining the method of measuring velocity that will secure a proper degree of accuracy.

It is found most convenient in current-meter work to divide the stream into parts 1, 2, 4, 5, 10, 20 feet in width, depending on the size of the stream and unevenness of the bed and to find the area, the mean velocity, and the discharge through each part separately. The total discharge is the sum of the discharges through the parts.

Fig. 1 (page 12) shows a meter station where measurements are made from a car suspended from a cable. The tags on the tag line directly over the cable mark the points where measurements of depth are made. The inclined gage is shown on the left side. The cross section is shown divided in parts by vertical lines directly over the tags. The dotted curved lines in the cross section are lines of equal velocity. The figure shows velocity being measured under one of the tags.

Soundings.—Soundings should be taken at intervals across the stream, sufficiently near together to enable the cross section to be computed to the required degree of accuracy. The distance between the soundings should depend upon the size of the streams, evenness of the bed, and the degree of accuracy required. For small streams, the interval may vary from 2 to 4 feet; for streams of moderate size, from 5 to 10 feet; and for larger streams from 10 to 20 feet, except around obstructions, where they should be taken about 5 feet apart.

A small, round weight is not so good for sounding as a large, flat one, because if the bed is soft or rough the former will settle into the bed or between the projections and give too great a depth.

When a very heavy weight is used for sounding in swift water it is well to have foot and half foot marks on the sounding line, so that the depth can be read when the lead rests on the bottom. Different colored bits of ribbon firmly tied to the sounding line and wrapped with insulating tape will generally answer the purpose. The part of the line that is immersed may preferably be of picture wire.

On account of the great difficulty of obtaining accurate soundings at high stages of water, depths for flood measurement should be com-

puted from soundings taken at a lower stage, either just before or just after the flood, provided the channel is of a permanent character.

The soundings can be taken with the meter on the line when the velocity in a vertical is being measured if the velocity is less than 3 feet per second. Care must be taken, however, to lower the meter gradually and not allow it to suddenly strike the bottom.

In sounding in a swift current the lead should be directly underneath the point of observation and the line should not be bowed downstream. When the bed is very uneven two or more measurements of the depth at each point should be taken and the mean used. This can easily be done by holding in one hand the point on the line which touches some well-defined point on the bridge when the lead rests on the bottom, and comparing this point with the corresponding points on the line obtained by two or more trials. The distance measured on the line from the point obtained as the mean of these two or three trials to the point on the line when the lead is drawn up so as to just touch the surface of the water is the mean depth. When more than 40 pounds of lead are used on the meter a cotton rope should be used for handling it, as the cable is not strong enough.

The initial point for soundings should be so marked that it can easily be recognized, and the points at which soundings are made should be clearly marked on the bridge or on the tag line of the cable or boat station.

MEASUREMENTS OF VELOCITY.

General statement.—Velocity should be measured in each vertical where a sounding is taken except where the change is small, when it should be measured in alternate verticals. Several methods are in use for obtaining mean velocity in a vertical. They may be classified as single point, multiple point, and integration. In velocity observations the revolutions of the meter wheels should be counted for two equal periods so as to check the count. These periods are usually 50 seconds each.

Single-point method.—Three single-point methods are in general use. In one, usually called the 0.6-depth method, the meter is held at the depth of the thread of mean velocity; in another, called the flood method, the meter is held 1 foot below the surface; in the third the meter is held at mid depth. In each of these methods it is necessary to apply a coefficient to reduce observed velocities to mean velocities. The advantage of the first one is that it is rapid and simple and the coefficient is unity. The advantage of the second is that it is the only method that can be used during a flood. The third method is seldom used.

The mean-velocity method, ordinarily called the 0.6-depth method, will give very good results where the conditions are good—that is,

where there is a nearly straight channel with little obstruction, a bed regular in shape, and no sudden changes in velocity. The thread of mean velocity for such condition varies from 0.55 to 0.65 of the depth, its position depending on the depth, the ratio of width to depth, and the roughness of the bed. For broad, shallow streams with gravelly beds, of depth from 1 to 3 feet, holding the center of the meter 0.57 depth below the surface will give satisfactory results. For ordinary streams, of depth from 1 to 6 feet, holding the center of the meter at 0.6 depth below the surface will give satisfactory results.

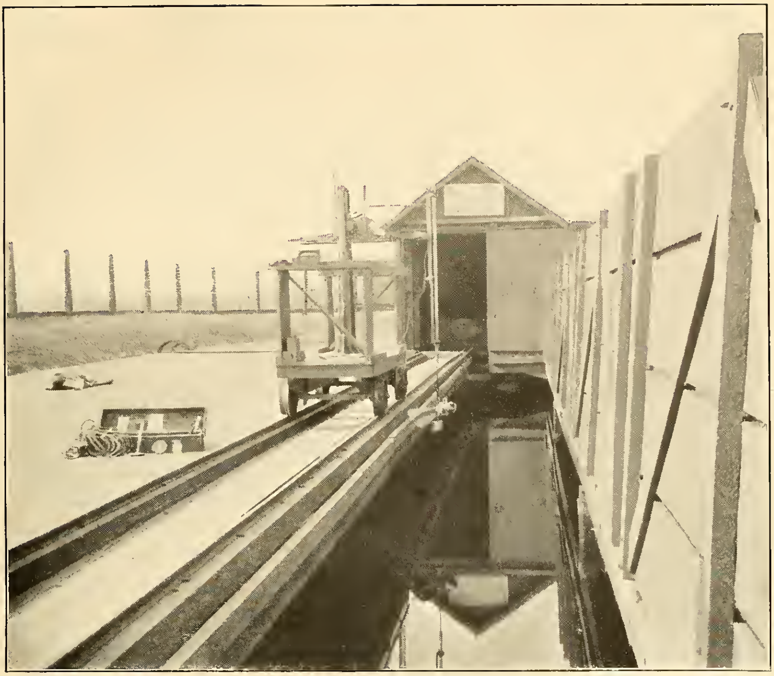
The flood method is to be used in making measurements at very high stages, when the single point and integration methods can not be used. The meter should be held 1 foot below the surface and a coefficient applied to the measured velocity to reduce it to mean velocity. The value of this coefficient varies from .85 to .90. An easily recognized mark on the meter line, one foot above the center of the meter, will be found useful in keeping the meter at the proper depth. (See also flood measurements, p. 23.)

Integration method.—In the integration method the meter is kept in motion either from the surface to the bottom and back again to the surface in a vertical line, or diagonally from the surface to the bottom and back again to the surface, while it is at the same time moved across the channel. The latter, called the zigzag method, is seldom used, except in comparatively small artificial channels.

The vertical-integration method, consisting of moving the meter from the surface to the bed and back again to the surface, counting the number of revolutions and noting the time, gives satisfactory results if the meter is moved slowly and at a uniform speed. It is a better method than the others where time is limited and where the conditions are poor (crooked channel, obstructions, etc.); also where the surface is retarded by drift, logs, or ice. It is a very good method for checking results obtained by the single-point method. This method is more difficult for one man than the point methods, and gives somewhat less information.

Multiple-point methods.—These consist of top and bottom; top, mid depth, and bottom; and vertical velocity curve. In the top-and-bottom method mean velocity is taken as the half sum of the top and bottom velocities. In the top, mid-depth, and bottom method the mean velocity is taken as one-fourth the sum of the top and bottom velocity and twice the mid-depth velocity. $V=\frac{1}{4}(T+B+2M)$. In the vertical-velocity-curve method the mean velocity is computed from the velocities observed at several points in each vertical, as shown on pages 50–51.

The top-and-bottom method does not give satisfactory results where the bed is uneven. The results are, as a rule, too small. In a very shallow stream, 3 to 12 inches in depth, with sandy or fine gravel bed, satisfactory results are obtained by this method if the center of the meter is held 0.15 of a foot below the surface and the same distance



A. CURRENT METER RATING STATION AT DENVER, COLO.

B. METHOD OF MAKING DISCHARGE MEASUREMENT BY WADING.

above the bed. If the bed is coarse gravel (particles 1 to 2½ inches in diameter) the center of the meter should be held 0.15 of a foot below the surface and from 0.3 to 0.4 of a foot above the bed.

The vertical-velocity-curve method should be used when there is abundant time, for it gives more accurate results than either of the other methods, but it requires so much time that it is seldom employed except to check results obtained by one of the other methods. From three to eight observations are necessary in each vertical, each requiring from 50 to 100 seconds of time. A few vertical-velocity curves should be obtained at certain selected points in the cross section if possible.

Low velocity limitations.—The current-meter and weir discharge comparisons made at the hydraulic laboratory of Cornell University, described in Water Supply Paper No. 64, show that current-meter measurements of velocities less than about 0.4 or 0.5 foot per second are not reliable. The meter discharge is less than that shown by the weir, the error increasing as the velocity decreases and as the friction of the meter increases. For these reasons it is not advisable to attempt the measurement of the discharge at a place where the mean velocity is less than about half a foot per second. Inasmuch as there is always a small area of low velocity near the banks and around piers, a rule was made by the hydrographer in charge, March, 1903, that hereafter when the velocity at a station becomes less than half a foot per second in more than 15 per cent of the cross section, the measurements there should be discontinued. At many stations where current-meter measurements can not be made when the flow becomes sluggish at low stages, a place can be found within half a mile of the station where the velocity can be measured by wading.

At each permanent gaging station where a high degree of accuracy is required a somewhat extended study should be made at different stages by the vertical-velocity-curve method to test the reliability of the results obtained and to derive coefficients applicable to other stations having somewhat similar conditions.

Measuring discharge by wading (*see Pl. II, B*).—Discharge can often be measured more accurately than at the gaging station by wading in some chosen section where the conditions are good. Iron rods three-eighths inch in diameter and at least 3 feet long, with a long slot or thumbscrew in one end and the other end pointed will be found convenient for holding the ends of the tape during the measurements. Depth can be measured with a light rod, marked to feet and tenths, that can be made in a few minutes. The hydrographer should hold the meter as far to the side of him as possible and a little upstream so that there will be but slight obstruction offered by his body (see Pl. II, *B*). In a very small stream measurements should be made from a plank laid across it instead of by wading.

CHECKS.

The field work of the discharge measurement should not be considered complete until it has been checked. The chain gage can be checked with a steel tape, as described on page 16. The observations of velocity can be checked rapidly by the integration method, and the computed discharge partially checked by plotting it on squared paper and comparing with station rating curve of the preceding year. If any discharge varies from the station rating curve by more than 5 per cent for ordinary stages at a station where the conditions are fair to good, or by more than 8 per cent where the conditions are fair to poor, the hydrographer should seek the cause in change in channel or in mistakes.

CLASSES OF DISCHARGE MEASUREMENTS.

Minimum-flow measurements.—Records of the minimum flow of a stream are in nearly all cases very important, and special effort should be made to secure them every season at each important station. It is not very important to determine the smallest amount that flows past the station during the season, for this minimum may occur when the greater part of the natural flow is being held back by dams; what is desired is the average flow for the month or week when the flow is least.

A larger number of discharge measurements are necessary to define the lower part of the station rating curve than any other part, because small changes in gage height have a much larger proportional effect on the discharge for the lower stages than the higher ones, and because the slope changes faster in the lower than in the higher parts of the curve.

When there are daily fluctuations in the discharge—as, for instance, where the water is held back by dams—care should be taken to have the gage read at such times that the reported "daily gage height" is the mean for the day; for example, if a gage is below a dam that holds back the water during the night, one reading should be taken when the water wheels are in use and one when they are shut down.

It is often advisable to have a low-water gage in addition to the one for other stages, one that can be read by the observer easily and with a greater degree of accuracy.

Facts in regard to the minimum flow of tributaries of each stream and their suitability for power and water-supply purposes should be collected by the hydrographer and reported to the Washington office, on form 9–213 or by brief reports. It is well to give also the dates and amounts of precipitation in inches at the nearest Weather Bureau station for some days preceding the date of measurement. Such facts can usually be obtained at small expense, and they add greatly to the value of the discharge records.

Flood-flow measurements.—The stage of a stream during flood usually changes so rapidly that a discharge measurement made at such a time, to be of greatest value, should be made in less than two hours; three or four observations of the velocity 1 foot below the water surface between each pier and one or two between each pile pier will usually answer this purpose. Depths can be obtained from previous soundings at a lower stage or from the cross section of the river at the station, developed after the flood.

Care must be taken to protect the current meter from injury by drift.

When for any reason the meter can not be used, the surface velocity can be obtained by means of floats.

In wide streams where the conditions between piers are similar, if the velocity is 5 or more feet per second and the bridge spans are 150 feet or more in length, it is not wise to attempt to measure velocity nearer to a pier than about 25 feet. When the measurement is taken the area of the pier should be neglected in computing the discharge. If the velocity is less than 5 feet per second the area of the pier (or piles in the case of trestle work) should be subtracted from the area in computing the discharge.

The gage height at which overflow of banks takes place should be noted, also any backwater effect. Facts in regard to character and extent of damage done by the flood should be obtained; also effect of obstructions upon the height of the flood.

Distribution of discharge measurements.—As far as possible discharge measurements should be made at such river stages as will give a point on an undefined part of the station rating curve. Frequently there are several measurements made at about the same gage height and no measurement for 2 or 3 feet stage above or below them. By instructing observers to telegraph when the river reaches a desired stage the hydrographer can time his visit so as to obtain a point on the curve at which no measurements have been made.

Very often the hydrographer can obtain two or more points on the rating curve at a single visit. By remaining a couple of days at the station when the stage is high he can make four or more discharge measurements cheaply, which may serve to fix a considerable part of the curve.

Miscellaneous discharge measurements.—A miscellaneous discharge measurement is one that is made at a distance from a permanent or temporary gaging station. The place of measurement should be referred to some easily found landmark—as, for example, "500 feet upstream from county bridge, 3 miles northwest of ———," and the elevations of the water surface should be referred to some point that can be easily found and again used—as, for example, "10 feet below upper surface of floor beam, first span north end Southern Railway bridge, 3 miles south of ———." Facts in regard to the behavior of the

stream, its minimum and maximum flow, and a comparison between the discharge at the time of measurement and low flow should be ascertained and reported.

When measurements are made at several places along a stream during a reconnaissance, allowance should be made for rain that has fallen in the interval between measurements between the places and on tributaries entering the stream between points of measurement.

Winter discharge measurements.—The winter discharge of the important streams is desired at permanent gaging stations, where the conditions are such that reliable data can be obtained at reasonable cost. If ice does not interfere with the work, it should be continued during the winter, as at other seasons of the year.

If anchor ice forms at a station, a record should be kept showing the date of its formation, the height of backwater due to it, and whether much or little water is flowing at the time. Facts in regard to the rise in the stream that lifts the ice but does not clear the channel should be noted.

At stations where solid ice forms, the observer should visit the station at least once a week to read the gage and note the condition of the stream. If the gage is a chain one, the ice should be cut away around the gage, the gage read, and the thickness of the ice measured, also the distance of the surface of the water above or below the surface of the ice. The observer should also note whether the ice is rough or smooth on the under side and the distance to open water above and below the station.

A rod with a crosspiece on the lower end, forming a T, is convenient for measuring the thickness of ice.

The vertical-integration method of measuring the velocity (by moving the meter slowly from the surface to the bed and back to the surface again, counting the revolutions, and noting the time) will be found satisfactory under ice. Some vertical velocity curves, however, should be taken at each measurement. A special station rating curve must be used for periods when ice interferes with the natural flow.

GAGE READINGS.

Computations of discharge and run-off are usually based on gage readings taken one or more times daily. If any of these are in error, the results obtained from them are in error also. Every effort should therefore be made by the hydrographer to secure thoroughly reliable gage readers. No pains should be spared to teach them to read the gage correctly and to properly record and report the readings. They should realize the importance of the records they are taking, and should know that means are being taken to see that the records are reasonably correct.

At each visit to the station the hydrographer should examine the gage reader's book and make comments thereon. The reading of the observer and hydrographer on the day of visit should be compared.

A gage reader is more likely to read with regularity and accuracy a gage that can easily be reached and seen than one which requires unusual effort or risk to read; hence, except in rare cases, a chain gage should not be placed on a high railway trestle bridge, nor on a structure where it is necessary for the observer to climb, nor where he is obliged to kneel down and reach out over some part of the structure.

Rod gages frequently become waterworn and covered with dirt, so that they are difficult to read. Occasionally the bed fills in around the lower end of the gage, so that it is necessary to keep open a channel of running water to the gage. These points and many others the hydrographer must keep in mind and provide for in order to secure satisfactory records of daily gage heights.

STANDARD CROSS SECTION.

There should be prepared for each permanent gaging station a cross section of the stream showing the contour of the channel to points on each bank above the highest flood water, the piers, and other obstructions, and showing elevations referred to the zero of the gage. An engineer's level or plane table will be necessary for this purpose. From such a cross section approximate depths can be found for any gage height; also changes in channel due to scour or fill. It also assists very materially in the preparation of the station rating table.

DATA ON FLOODS.

Hereafter there will be prepared at the end of each year a water-supply paper on the destructive floods of the year, showing their magnitude and extent, the destruction wrought by them, and the engineering features involved in the prevention of their destructive action. When a notable flood occurs in the area in charge of any district hydrographer he should make a special effort to visit the locality during the flood, or very soon thereafter, and obtain all facts possible concerning the height, quantity of water, destruction wrought, and reasons therefor, and prepare a report thereon, adding comments concerning the action of bridges, buildings, levees, etc., along the stream. In such investigations care should be taken to verify data not obtained from actual observation, especially any data necessary for computing discharges. If discharge is computed from data obtained principally from flood marks, special care must be taken, because these marks are often misleading.

RECONNAISSANCE.

A reconnaissance of a stream is made for the purpose of locating a gaging station, investigating water power or water storage possibilities, or studying the destruction wrought by floods or the pollution of the water.

All data that have any bearing on the question studied should be collected, and sketches should be freely used, showing the relative positions of objects described. The notes should be very full and clear, so that they will convey correct ideas of facts after they have been in part or wholly forgotten.

A reconnaissance for the selection of a gaging station or for investigating power and storage possibilities is usually made when the stream is low, as data collected for these purposes are more valuable at this stage than at the high stages.

The instruments used are a hand level, compass, steel tape, and current meter.

The topographic features of the watershed, such as the elevation, slopes of surface, width of valleys, character of rock and soil and vegetation, should be noted; the slope of the stream, location of the used and unused power, location and magnitude of principal tributaries, high-water marks, the extent to which the water is used for industrial purposes, kind of industries, and the kind and sources of pollution should also be noted.

The discharge of a stream and its principal tributaries should be measured, and a temporary bench mark should be left at each point of measurement, so that if a subsequent measurement is made at that point it can be compared with the former.

DESCRIPTION AND CARE OF INSTRUMENTS.

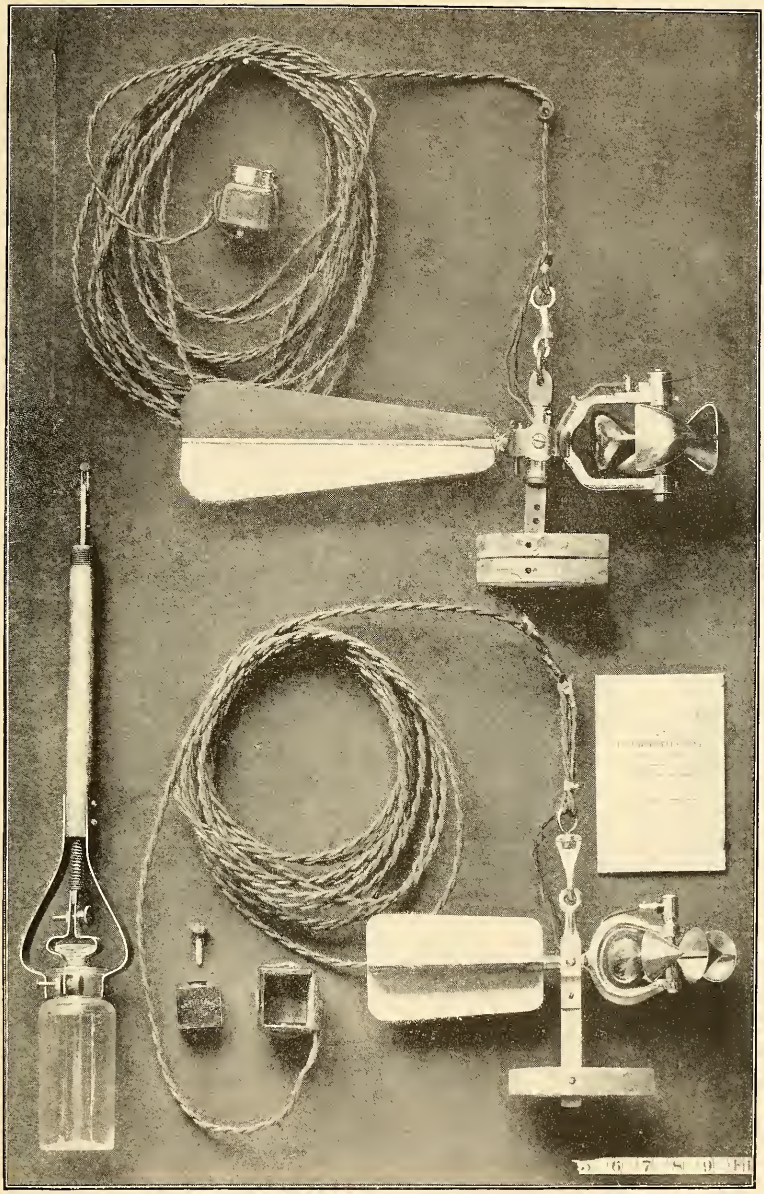
GENERAL STATEMENT.

Hydrographers are responsible for the care of current meters and other Government instruments intrusted to them, and are required to account at stated times for all such property in their keeping. Since the accuracy of stream gagings depends largely upon the correct working of the current meter, great care should be exercised in handling these instruments and in keeping them properly adjusted. Inaccurate work and poor results can often be traced directly to neglect in caring for instruments.

CURRENT METER.

The following description and suggestions regarding the use and care of the small Price electric current meter (see Pl. III) are intended for the guidance of hydrographers in the field:

When in use the meter is suspended by a double conductor cable of No. 14 or No. 16 flexible copper wire, heavily insulated. Wire of that



PRICE ELECTRIC CURRENT METERS, WITH BUZZERS.

size is of sufficient strength to hold the meter and weights, and it obviates the necessity of additional rope for suspending the equipment when the weight used is less than 40 pounds. The cable is attached to the meter with a spring snap hooked into the circular end of the trunnion P, fig. 5. The heavy copper wires are connected with the meter binding posts *h* and *d* by smaller and more flexible wires. The wires connected with the binding post *d* should be threaded through the metal loops on the yoke *o*, within the trunnion frame, and at *g*. It is desirable that these wires should be flexible and loose, to allow the meter to swing free in the vertical plane when it is in use.

Lead weights (*a*, fig. 6), provided for the purpose of holding the meter steady in moving water (the higher the velocity of the stream

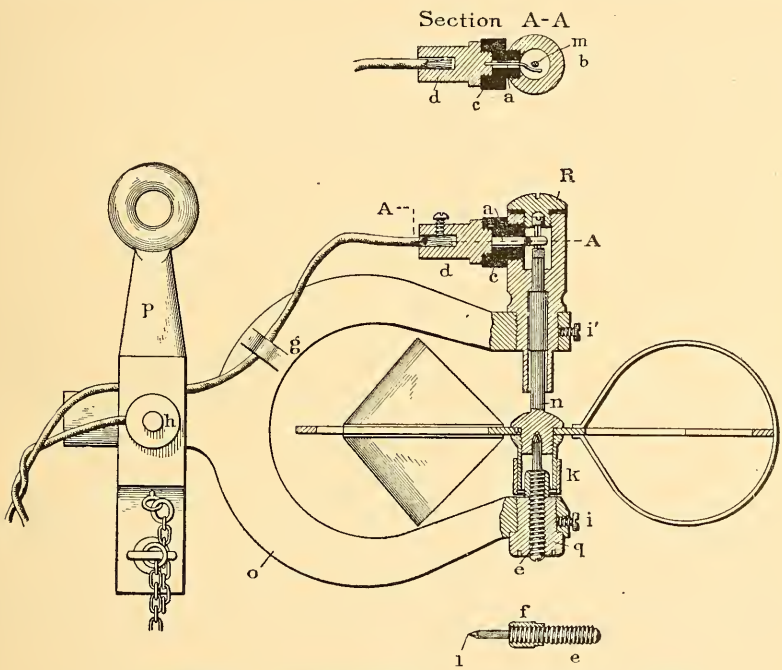


FIG. 5.—Cross section of small Price electric current meter, showing details.

the greater the weight), are attached to the lower end of the trunnion by means of a detachable weight stem (*b*, fig. 6).

The weight vane (*c*, fig. 6) should be attached to the weights at all times when the meter is used suspended from a cable. When gaging small or shallow streams it may be necessary to make observations by wading. Under such circumstances it will be more convenient to dispense with the lead weights and attach the meter to a light rod or pole. If desired a brass standard can be supplied for attaching the meter to the rod.

The meter is supported in a trunnion or hanger (P, fig. 5), and is free to swing in a vertical plane. One revolution of the wheel or cups is

indicated by a buzz of the electric buzzer, the observer being required to count the number for a certain interval of time, preferably fifty seconds, as the computations can more easily be made from that number. A second observation of the same length of time should immediately follow the first observation in order to verify the count.

The vertical axis (*n*, fig. 5) to which the cups of the current-meter wheel are attached, and hereinafter referred to as the cup shaft, terminates at the lower end in an inverted cone, which bears or turns on the cone-shaped point of *e*, fig. 5. The part marked l, fig. 5, will be referred to as the point bearing. This is the most delicate part of the meter, and should be treated with the greatest care, as it is made of highly tempered steel and is liable to be fractured or broken. To protect this sharp point bearing while the meter is being shipped or carried, a milled sleeve (*k*, fig. 5) is provided. This sleeve is threaded on the inside, and screws up or down on the screw thread on the extension of the lower end of the cup shaft shown in fig. 5. When the meter is not actually in use, and before it is put into the wooden

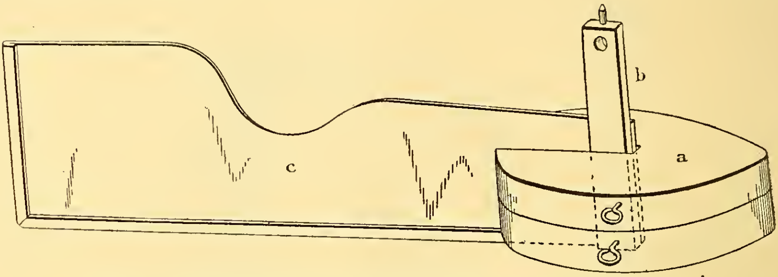


FIG. 6.—Weights and weight vane of small Price electric current meter.

case after using, the milled sleeve *k* should be screwed down until it bears on the top of *q* and raises the cups and cup shaft off the point bearing, thus protecting it from possible injury. This sleeve should not be screwed down very tight, as the shoulder of the journal on the upper end of the cup shaft will be thrust hard against the end of its bearing and perhaps be injured.

When preparing to make a measurement with the meter the milled sleeve should be screwed up on the cup shaft far enough to make it absolutely certain that the cups are turning on the point bearing and are working with the least possible friction. This sleeve is milled for adjustment with the fingers and not with a wrench or pliers.

If the point bearing becomes injured and it is necessary to replace it, an extra one will be found in the meter case. To replace the bearing slacken the screw *i*, fig. 5, with the small spanner wrench provided with the meter, remove the large nut *q* with the point bearing locked in it. After its removal hold the head of the nut *q* firmly with a small wrench or pair of pliers, slip the small spanner wrench over

the flat sides of the nut *f*, and loosen it. Remove the nut *f* with the fingers, and with a small screw-driver take out the damaged bearing from the large nut *q*. Replace the large nut *q*, and with the spanner wrench screw it firmly into yoke *o*. Remove the lock nut from the point bearing to be inserted, and with a screw-driver send the latter through the large nut *q*. Great care should be exercised in making this most important adjustment of the current meter. A slight amount of play or movement of the cups up and down must be allowed, so that they will revolve freely and without friction. When the point is almost up turn it, a part of a revolution at a time, with the screw-driver, until the proper adjustment is obtained. After the adjustment has been made a full turn of the point bearing in the nut *q* would crush the sharp point of the bearing *e* into the inverted cone of the cup shaft and break the point. After the point has been satisfactorily adjusted remove the nut *q*, with the point in it, put the lock nut on the point, and draw it down on the face of the large nut and thus preserve the adjustment. Should the adjustment of the meter be too tight the results obtained from its use will be erroneous. An examination of the meter when received from the Survey will give an idea of the proper adjustment. Do not disturb the adjustment of the meter unless it is necessary to put in a new point bearing.

Section A–A, fig. 5, shows the construction of the binding post and contact spring of the meter. A flexible, well-insulated copper wire (No. 20, or smaller), is drawn through the metal loop *g* of the yoke *o*, and the end of the wire free from insulation is thrust into the metal binding post *d* and secured by the small set screw. This metal binding post terminates in a slender platinum spring (*a*), which extends through the hard rubber nipple *c* into the contact chamber to *m*. The top or upper end of the cup shaft terminates in the contact chamber with an oval-shaped eccentric (*m*), which makes a contact with the spring *a* at each revolution of the meter cups. This contact can be prolonged or shortened by bending the point of the contact spring in the contact chamber in the desired direction. The oval-shaped eccentric end of the cup shaft is detachable, and can be removed by taking off the cap R, holding the cups firmly, and applying a screw-driver to the small slotted head.

The insulating nipple *c* is made of hard rubber, and is likely to break if the binding post *d* receives a sharp blow. An extra insulating nipple will be found in the small tin case in the meter box. Before removing or replacing the binding post *d*, take out the eccentric-shaped top of the cup shaft *m*. If this is neglected the contact spring will be destroyed by the turning of the binding post.

In using and handling the meter care should be taken that it does not fall or get a hard knock which may injure the cups or cup shaft.

An injury to either will change the rating of the meter, and if this occurs it should be immediately returned to headquarters for repairs. When using the meter in streams containing grass or moss, examine the instrument frequently to see that nothing has lodged on or wrapped around the cup shaft *n*.

If the meter has not been used for some time before a measurement is made it should be carefully cleaned and oiled.

BATTERY AND BUZZER.

In charging the battery cell used with the electric buzzer furnished with the current meter, one-half teaspoonful of bisulphate of mercury is sufficient. Fill the cell with water and insert the zinc pole with the rubber stopper attached. When putting the battery cell in the leather case be sure that the small platinum point on the lower end of the cell and the screw head of the rubber stopper make perfect contact with the copper plates. If the buzzer makes but a faint clicking sound instead of a buzz, remove the metal cap covering the buzzer, and with a knife blade adjust the small upright brass point by bending until the armature produces the desired sound. Never allow the liquid to remain in the battery cell over night, as it will generate gas and produce pressure sufficient to cause the cell to leak at the rubber stopper, and the solution escaping will destroy the leather of the brass parts of the buzzer. When measurements are needed requiring a long time for completion the stopper should be removed occasionally to relieve the pressure due to the gas.

When preparing to make a discharge measurement charge the battery cell of the buzzer, remove the meter from the case, take out the weights, weigh stem and vane, combine them as in fig. 6, and attach them to the meter with the spring pin provided; turn up the milled sleeve *k*; be sure that the meter is well oiled, and turn the cups to see that they revolve freely and that the buzzer responds to each revolution.

After making a discharge measurement, or at the close of a day's work with the meter, unscrew the large nut *q*, with the point bearing in it, and examine the point carefully to detect injury. With a piece of soft cloth remove the water in the opening at the lower end of the cup shaft, oil generously, and replace the bearing. Then remove the screw cap R, turn the meter over to allow the water to run out of the contact chamber, put in a plentiful supply of oil, and replace the cap; this protects the top of journal bearing of the cup shaft from rusting. After this has been done turn down the milled sleeve *k*, to protect the point bearing while carrying the meter, remove the battery cell, empty out the liquid, wash the cell with water, and pack the meter carefully in the case, when it will be ready for future use.

RERATING OF METERS.

Whenever a meter point is found to be broken or injured it should be replaced by the other point bearing which accompanies the meter. If the cups are injured or the cup shaft is bent the meter should at once be sent to headquarters for repairs. Every meter that has been used to any considerable extent after rating should be rerated before the beginning of the next field season.

For description of meter-rating stations and method of rating meters see Water-Supply and Irrigation Paper No. 56, page 34.

The rating table of a small Price meter when held with a rod differs somewhat from that applicable to a similar meter when held with a cable and free to tip, so that if this meter is used with a rod care must be taken to employ the proper rating table.

RECORDS AND REPORTS.

General statement.—The regulations which govern all work done by the United States Geological Survey require that all original records of data collected shall be filed for public reference at the office of the Survey, in Washington. These records should be so clear and full in all respects that they will be intelligible at any time to engineers and other persons who may desire to consult them.

Duties of district hydrographers and engineers.—In order to systematize stream measurements the country has been divided into districts, each of which has been placed under the supervision of a district hydrographer or engineer. It is the duty of this officer to superintend all stream measurements in his territory, and he is held responsible to the chief engineer for the character of the work done by the men under him. He should have immediate supervision of all the more important features of the work which can not be intrusted to his assistants. The stream-gaging work, which is carried on in connection with the investigation of irrigation projects, should be under the direct charge of a man designated by the district engineer, through whom he shall report. This man should be held responsible for the proper execution of all stream-measurement work, and all data concerning such work must be transmitted through him.

Care in keeping records.—As the work of the Government is for the general public, it is subject to more severe criticism than the work of private engineers. It is therefore essential that great care be taken in the work and that every possible excuse for criticism be eliminated. All necessary notes should be taken in the field, and, as a special precaution, at the end of each day's work notebooks should be reviewed and amplified while the facts and conditions are still fresh in the mind of the hydrographer or engineer. Careful cross references should be

made, and sketches to show the relative location and details of special features should be freely used.

Computing field notes.—Original computation of all field notes should be made, when possible, in the field, or the notes should be computed at as early a date as possible, and in no case should the hydrographer allow large quantities of undigested data to accumulate.

Checking of records.—All records and notebooks should be examined and checked before they are transmitted to the Washington office. In order to fix the responsibility for errors each book or sheet should be stamped and initialed "Computed by ———," "Computations checked by ———," or "Examined by ———." All records are carefully examined at the Washington office, and if incomplete they will be returned to the district engineer or hydrographer for correction and amplification.

Duplicate records.—The district hydrographer may cause to be prepared such duplicate copies of original notes as may be necessary for reference in his office. Too much duplication should be avoided. The original records may be loaned at any time from the files of the Washington office.

Transmission of data to Washington office.—All data, correspondence, and other material from each hydrographic district should be transmitted through the district hydrographer or engineer to the Washington office. This material should be initialed by the district hydrographer or by some one designated by him. With the exception of single gage-height and discharge-measurement cards, mailed as postal cards, all data sent should be accompanied by a letter stating the amount and character of material furnished. No data will be accepted by the Washington office which is not O. K.'d by the district hydrographer or by some one designated by him.

Standard forms.—As far as possible the standard forms furnished by the Survey should be used in transmitting data. Such information as can not be written on these forms and cards may be transmitted on the separate sheets of paper furnished by the Survey. These sheets should be of the standard letter size, 8 by 10 inches, as this is the size for which the file boxes of the Washington office are designed. Pieces of paper of odd sizes should not be used either for drawings or reports. Sketches and maps accompanying reports should, whenever possible, either be on paper of standard size, or should be folded to conform with this size in order that they may be filed with the written reports.

The following is a list of the forms which have been adopted for general use in hydrographic work. These are intended both to minimize and simplify the work. Whenever forms become too numerous they lose their usefulness. Every effort has, therefore, been made to

reduce the number of forms to a minimum and to prepare these in the simplest manner possible.

List of standard forms.

GAGE-HEIGHT FORMS.

Form 9–176.—Gage-height cards, for transmitting observer's daily gage readings to the resident and district hydrographer, to be forwarded to the Washington office.

Form 9–175.—Observer's gage-height books, for recording daily gage-heights at river stations.

Form 9–212.—Daily gage-height form, for tabulating daily gage-heights, arranged by months, with sufficient space for one year's records.

DISCHARGE-MEASUREMENT FORMS.

Form 9–198.—Current-meter notebooks for recording notes of discharge measurements, vertical-velocity curves, and other meter work.

Form 9–221.—Card for reporting discharge measurements to the Washington office.

Form 9–207.—For tabulating discharge measurements for regular stations, with spaces for all necessary data.

Form 9–223.—For tabulating miscellaneous discharge measurements.

Form 9–244.—For describing the method of and for reporting miscellaneous discharge measurements made by floats, to be used in regular work.

COMPUTATION FORMS.

Form 9–192.—For tabulating daily gage heights and their corresponding discharges, with spaces for totals, monthly means, and run-offs. The form provides for one year's records, arranged by months.

Form 9–210.—For tabulating station rating tables.

Form 9–206.—For tabulating meter rating tables.

REPORT FORMS.

Form 9–197.—Description of river stations; to be used for describing both temporary and permanent stations.

Form 9–237.—For reporting the conditions at river stations and giving the cost of maintenance.

Form 9–213.—For reporting changes and other information in regard to river stations.

Form 9–171.—Monthly report on river stations.

Form 9–245.—Monthly report of services, giving daily employment.

VOUCHERS AND MISCELLANEOUS FORMS.

Form 9–230.—A blank form ruled for miscellaneous tabulation.

Form 9–904.—Cross section notebook.

Form 9–903.—Level notebook.

Form 9–253.—Index blanks for notebooks.

Form 9–019a.—Subvouchers.

Form 9–009.—Service vouchers for field men.

Form 9–005.—Field vouchers.

Form 9–015.—Traveling expense vouchers.

Form 9–918.—Expense account notebook.

Aside from these forms, which are in general use, there are several forms which are used in the Washington office and in special work.

Hydrographers desiring forms for any purpose will kindly forward a description of what they want, and they will, as far as possible, be supplied.

INSTRUCTIONS FOR USE OF FORMS.

Observers' gage-height books (*form 9–175*).—In the observers' gage-height books are recorded the daily stage of rivers, together with miscellaneous information, such as data in regard to floods, ice, weather conditions, etc. The observer should be instructed and trained to keep the books in as legible condition as possible, and to insure this the hydrographer should inspect the gage-height book at each visit to the station. At the end of each year the observer should be furnished with a new book and the old one should be returned to the district hydrographer's office, where it should be examined, checked, and forwarded to the Washington office for filing.

Gage-height cards (*form 9–176*).—Gage-height cards should be made out at the end of each week by the local observer and mailed to the district hydrographer's office, where they should be carefully examined. In this examination all missing data, such as the date, name of station, river, State, etc., should be supplied. The gage heights should be compared with the gage heights for previous weeks to see that no unaccountable changes due to error in reading the gage have been reported, and the column for means should be filled in. A copy of the data on the cards should be made for the office of the district hydrographer and the originals should then be forwarded to the Washington office.

Current-meter notebooks (*form 9–198*).—In these books are recorded the field notes of discharge measurements and vertical velocity curves. In all cases the original data should be written in the book at the time of the measurement. In no case should it be copied from rough notes in other books. Explanatory notes, cross references, and sketches should be added at the end of each day's work. The blank spaces at the head of each page are to be filled in; also the columns for the original data. In the column headed "Depth of observation" the exact depth for each observation should be recorded; "at 0.6 depth" is not sufficient; the position of the initial point, edges of water, edges of dead water, and number of channels should be stated; also the direction and force of the wind, roughness of the bed, and any other factors on which the accuracy of the work depends. A statement of the reliability of the results should be made in the notes. If the measurement is not made at the station the approximate distance and a brief statement of the conditions at the places of measurement should be made. The velocity at the water's edge and at the edge of piers, shoals, etc., should be estimated and recorded. The

cross-section pages at the end of the book are to be used for sketches and additional explanatory notes. Cross-reference notes should be made referring to these pages. Page 48 shows a sample page of current-meter notes with the computations for the same.

Discharge measurement cards (*form 9–221*).—These are to be made out by the hydrographer and sent to the local office when the measurements are computed. Care should be taken to fill out all portions of the card. Special attention is called to the remarks and the portion for "gage verified and found" (see p. 16 for explanation). Measurement is not complete without this data. Either "At permanent station," "Temporary station," or "Miscellaneous measurements" should be crossed out, so that the card shows at once to which class of measurements it belongs. All cards should be carefully examined before they are sent to the Washington office.

Form 9–213.—In order that the office may keep a complete and systematic record of all the changes and additions at river stations, such as new gages, bench marks, changes in the river bed, equipment, etc., form 9–213 has been prepared. This form is to be used in sending in to the office any data in regard to the regular river stations which affect the measurements or the station in any way. These forms are filed with the regular data for the station, and are necessary in order that the Washington office may thoroughly understand the conditions under which the station has been maintained and the measurements made.

Description of river stations (*form 9–197*).—Special care should be taken in filling out the description of stations. The description should be so clear that with it a stranger could go to the locality and be able to continue the work at the station. The name of the station should be carefully chosen, and it should definitely locate the station with respect to some of the prominent features in the vicinity, as above or below some creek or tributary, at a certain bridge, near a certain township line, etc. If there has ever been another station on the same stream in the vicinity of the new station, the relative location of these two stations should be stated, and, if possible, the relation of the zeros of the two gages. In order to facilitate the preparation of rating curves it is desirable that care be taken in preparing a sketch of the cross section of the stream. This, with the other sketches, may be made on cross-section paper and attached to the description. It is also desirable to cut from a topographic sheet or some other map a section which will show the location of the station.

Indexing notebooks.—All notebooks should be carefully indexed on the regulation blank 9–253 before they are forwarded to the Washington office. The index slip should be left loose in the book, in order

that the file clerk may more readily check the contents. It will then be pasted on the cover. The following shows a sample of the indexing:

9-253

DEPARTMENT OF THE INTERIOR.

UNITED STATES GEOLOGICAL SURVEY.

HYDROGRAPHIC RECORDS.

Kind of notes, *Current-Meter.*
File No., *5399.*
Date received, *February 1, 1904.*
Hydrographers, *Chandler, E. F., and Richards, R.*

Stream.	Locality.	State.	Date.	Page.
			1903.	
Heart	*Church's ranch (Richardton).*	*N. Dak*	*S. 5*	*8*
Little Missouri	*Medora*	"	"	*7*
Mouse	*Minot*	"	*S. 25, O. 5*	*9, 11–12*
Pembina	*Neche*	"	*S. 28*	*10*
Red Lake	*Crookston*	*Minn*	*O. 12*	*13–14*
" "	*E. Grand Forks*	"	*Ag. 4*	*6*
Red River of the North	*Grand Forks*	*N. Dak*	*Ag. 1, 4*	*1–2, 4*
" " " " "	" " *(above forks)*	"	*Ag. 1, 4*	*3, 5*

NOTE.—Rivers to be arranged in alphabetical order. The same entries occurring several times should be entered but once and the various pages given.

If references are to consecutive pages use dash, e. g., 9–12; if not to consecutive pages, use comma, e. g., 1, 3, 5, 8.

Enter under the noun, except where the adjective is a recognized part of the name, thus, Platte, South fork; but North Platte, Little Missouri.

Kinds of reports.—Reports in general may be divided into two classes: First, the regular monthly reports of work accomplished; second, special reports transmitting data or information to the office. The regular monthly reports are intended to give the hydrographer an idea of the work that is being done and the progress that is being made. The reports containing data go into the office files as permanent records and are used in making up the publications. An effort should be made to maintain this division.

Use of maps and sketches.—In all reports, descriptions of stations, etc., maps and sketches should be freely used to show the location of river stations, the sections of the country visited, and other details. In case topographic sheets have been prepared for the region under investigation the hydrographer should supply himself with copies of these sheets and make use of such portions of them as cover the territory examined. Upon these maps special features should be shown. In the absence of topographic sheets land office and other maps should be used.

Report maps.—Each district hydrographer should prepare a map of his territory from the best maps available. This map should show,

with their names, the principal streams and other features on which work will be carried on. He should divide his territory into its principal drainage areas and indicate them on the map. When this division has been decided upon, it should be carefully adhered to, so that the measurements and other work can be referred to drainage areas. These maps may be prepared on tracing cloth, and from them the Washington office can make a paper negative, from which as many copies as desired can be supplied. This map is desired for use in reports. With each report a map should be transmitted showing the localities that have been investigated, which should be referred to by number, so that the chief engineer can at a glance see what is being done.

Monthly reports.—A monthly report of the district hydrographer is to be made up of—

(a) A brief written report stating what was done during the month and the condition of the work.

(b) Form 9–171, on which shall be given an alphabetical list of the river stations in each State in his district. Stations in different States should not be shown on the same sheet, as these sheets are filed by States, so that separate sheets should be prepared for separate States. In the column of remarks, such notes as "New bench mark established," "Station discontinued" (with date), "Station established" (with date), "Temporarily closed," etc., are to be given. Names of the stations which are temporarily closed should be kept on the list until they are discontinued.

(c) Form 9–245 is designed for use by each man under the district hydrographer. On this form should be briefly stated what the employee did on each day during the month. Such general statements as clerical work, field work, etc., are not sufficient. In preparing the monthly report it is suggested that the district hydrographer should have each man under him fill out form 9–245 and form 9–171 for the stations which he has visited. From these two forms the general monthly report can be taken.

Each field assistant and a distant hydrographer, when on field trips, should report to the district office immediately after visiting a station or after completing a reconnaissance or any piece of work, the general results of the work done, and such detailed information as is necessary in making up the monthly report for that district. This enables the district hydrographer to complete his report without waiting for the return of an assistant who is making an extended trip.

Resident hydrographer's monthly report.—The following is a sample form for monthly report of resident hydrographer:

ATLANTA, GA., *October 31, 1903.*

Mr. F. H. NEWELL, *Chief Engineer.*

DEAR SIR: The following is a report of hydrographic work carried on in the States of Alabama, Georgia, and Tennessee during the month of October, 1903:

The following men were engaged: Messrs. M. R. Hall, J. M. Giles, and O. P.

Hall of the regular force, and Messrs. W. G. Green and B. S. Drane of the temporary force. Their duties were as follows:

M. R. Hall had general supervision of the work, spent ten days in the office in general correspondence, preparation of descriptions, computation on meter notes, and miscellaneous duties. The remainder of the month was spent in making a reconnaissance of Flint River and its tributaries.

J. M. Giles spent the whole month in the field, making meter measurements, repairing gages, and establishing bench marks.

O. P. Hall spent the whole month in the office, plotting discharge measurements and making rating tables.

W. G. Green was employed for ten days during the month in making low-water measurements.

B. S. Drane was employed for twenty days during the month, ten of which were spent in the field assisting in the reconnaissance of Flint River; the remainder of the time was spent in the office working on the report of the work.

The accompanying lists show the distribution of the gaging stations in the various States; also the work done at each station. On the index map is indicated the location of the stations and of the localities investigated.

The accompanying reports and forms give a portion of the data mentioned in this report. The remaining data will follow in a few days.

Very respectfully,

M. R. Hall, *Hydrographer.*

9–171. DEPARTMENT OF THE INTERIOR.

UNITED STATES GEOLOGICAL SURVEY.

DIVISION OF HYDROGRAPHY.

Atlanta, Ga., October 31, 1903.

Mr. *F. H. Newell,*

In charge of Divison of Hydrography.

Sir: The following is a brief statement of the hydrographic work preformed during the month of *November,* 1903, under the direction of *M. R. Hall;*

RIVER STATIONS MAINTAINED, ESTABLISHED, OR DISCONTINUED.

Stream.	Station.	State.	No. of discharge measurements.	Remarks.
Alabama River	*Montgomery*	*Alabama*	0	*New B. M. established Nov. 15, 1903.*
Alabama River	*Selma*	"	1	
Black Warrior R.	*Cordova*	"	0	
Black Warrior R.	*Tuscaloosa*	"	0	*Discontinued Nov. 30, 1903.*
Cahaba River	*Centerville*	"	2	
Choccolocco Cr.	*Jenifer*	"	1	
Coosa River	*Riverside*	"	1	*Gage washed out, Nov. 10; replaced Nov. 20.*

Under "Remarks" state date of establishment or discontinuance, changes in gage, interruptions in observations, etc. A brief report covering any matters of interest occurring during the month, and form 9–245, should usually accompany this form. These make up the monthly reports of the resident hydrographers.

9–245. DEPARTMENT OF THE INTERIOR.

UNITED STATES GEOLOGICAL SURVEY.

HYDROGRAPHIC BRANCH.

Report of services rendered by *J. M. Giles* during month of *November*, 190*3*.

[To accompany vouchers form 9–009 or subvouchers 9–019, giving briefly the character of work performed each day.]

1. *Sunday.*
2. *Plotting discharge measurements, checking gage-height cards.*
3. *General correspondence and report on reconnaissance of Flint River.*
4. *Measured discharge of Alabama River at Salem, en route to Montgomery.*
5. *Measured discharge of Alabama River at Montgomery.*
6. *Computing discharge measurements and general correspondence.*
7. *Making up monthly reports.*

I certify that the services were rendered as above stated.

J. M. Giles.

Approved by *M. R. Hall.*

Reports on reconnaissance, surveys, investigations, etc.—As soon as practicable after the completion of the reconnaissance work, surveys, investigations, etc., a comprehensive report should be transmitted, stating concisely the information collected and the deductions which have been made, based upon the investigations. It is not desirable to accumulate data for a semiannual or yearly report. The material should be separated, as far as possible, into independent unit reports, and these should be transmitted as the work progresses.

Reporting new river stations.—When a river station is established a statement should be transmitted, together with a description of the station, on form 9–197, stating the general reasons for establishing the station and the conditions which led to its establishment at the particular site selected.

Authority for carrying on work.—At the beginning of each season or before starting work which involves a considerable expenditure of money, the hydrographer or engineer in charge should submit for the approval of the chief engineer a brief outline of the work which it is proposed to carry on. This should state the purpose for which the data are to be collected, the cost, and other details which will give the chief engineer an idea of what it is proposed to do. Approval of the plan is to be considered authority for carrying on such investigations as may be deemed necessary to accomplish the end desired.

Furnishing information to the public.—All data collected by Survey employees should be submitted to the Director through the hydrographer-in-charge before it is given to the public. In general, requests for data which are ready for distribution should be addressed to the

Director or the hydrographer-in-charge at Washington. When, however, requests are received by the district hydrographers or engineers they may furnish the information direct, if in so doing they are satisfied that the Survey will be in no way involved. Copies of all such requests and their answers should be sent to the hydrographer-in-charge for the Washington letter files. When the district hydrographer receives requests for data and he has some doubt concerning the advisability of complying with the request, he should prepare a letter containing the information desired, for the signature of the hydrographer-in-charge, who will decide whether the information should be given out. A carbon copy of the reply, with the answer and original request, should accompany the original request, so that a record of the data furnished may be kept in the Washington office.

Miscellaneous information.—It is expected that each district hydrographer and his assistants shall be on the lookout for any valuable information on the hydrography of the section in which they happen to be. This information should be systematically collected and carefully filed and indexed so as to be easily consulted. It is suggested that each employee supply himself with a small pocket case to hold 3 by 5 inch index cards. When in the field, items of importance may be noted on these cards, one subject to a card, and these, when filed in the office, will be a valuable source of information.

Publications containing progress reports of stream measurements.—The progress report of stream measurements for each year contains the results of the year's field work, including all original data, such as gage heights and discharge measurements, together with the office computations.

The following is a list of these publications by years:

1888. Tenth Annual Report, Part I.
1889. Eleventh Annual Report, Part II.
1890. Twelfth Annual Report, Part II.
1891. Thirteenth Annual Report, Part III.
1892. Fourteenth Annual Report, Part II.
1893. Bulletin No. 131.
1894. Sixteenth Annual Report, Part II. Bulletin No. 131.
1895. Seventeenth Annual Report, Part II. Bulletin No. 140.
1896. Eighteenth Annual Report, Part IV. Water-Supply Paper No. 11.
1897. Nineteenth Annual Report, Part IV. Water-Supply Papers Nos. 15, 16.
1898. Twentieth Annual Report, Part IV. Water-Supply Papers Nos. 27, 28.
1899. Twenty-first Annual Report, Part IV. Water-Supply Papers Nos. 35 to 39, inclusive.
1900. Twenty-second Annual Report, Part IV. Water-Supply Papers Nos. 47 to 52, inclusive.
1901. Water-Supply Papers Nos. 65, 66, and 75.
1902. Water-Supply Papers Nos. 82 to 85, inclusive.
1903. Water-Supply Papers Nos. 97 to 100, inclusive.

The supply of these publications is rapidly becoming exhausted, and many of them can be obtained only through members of Congress or by purchase from the Superintendent of Public Documents, Washington, D. C., or at some second-hand book store. District and resident hydrographers should endeavor to obtain a complete set of the above papers for their office files, and they and their assistants should familiarize themselves with their contents in order that they may know what work has been done by the Survey.

Miscellaneous hydrographic reports.—Aside from the publications containing yearly progress reports, mentioned above, special reports on various hydrographic subjects are prepared and published from time to time, in the series of Water-Supply and Irrigation Papers. These papers contain valuable information, and they should, as far as possible, be examined and studied by each man in the Survey, and special attention should be given to those relating to methods of the work.

COMPUTATIONS.

Rating curves and tables.—The object of taking gage heights and discharge measurements is to prepare rating curves from which a discharge table can be constructed. The practicability of applying a table depends on the general assumption that the discharge is a function of the gage height, and that for streams of practically constant cross section the discharge for the same gage height will be the same. By plotting the discharge measurements as abscissas and the corresponding gage heights as ordinates a discharge curve for the station can be drawn which will form a basis for the rating table. In preparing the rating curve a careful study of all available data should be made, and it is here that notes in regard to the various conditions at the time measurements were made are of great value. In choosing the scale for plotting the curve the maximum gage height and discharge should be considered. Its size should be such that the discharge can be read from the curve to the required degree of accuracy, and it should also be such that the inclination of the rating curve will be approximately 45°, for when the curve becomes nearly horizontal it is more difficult to accurately take the discharges from it. It is desirable to plot the measurements for different years on the same sheet, in order that a comparative study may be made of them. In plotting the discharge measurements different colors or symbols may be used to distinguish between measurements for different years.

The first draft of the rating table is taken from the curve. The table is afterwards smoothed out by adjusting first, and if necessary second, differences. The difference between the discharges for successive tenths should either be constant or increasing, never decreasing, and as far as possible it should follow some general law. Whether in the table the discharge should be carried out to the nearest second-foot or only to

the nearest five or ten second-feet, should be determined by the conditions at the station.

Figs. 7 and 8 are opposite extreme cases of rating curves. Fig. 7 shows one constructed from measurements carefully taken, and it also shows that it is necessary to have measurements made between gage heights 5.2 and 6.5 between which points the curve is not well determined. Fig. 8 shows that either the conditions at the rating station are poor or that the measurements are not being carefully made. When such conditions as are shown on this curve are encountered the district hydrographer should make a careful investigation to determine some solution of the problem.

Computation of daily discharge, monthly means, run-off, etc.—The object of the rating table is to enable the computation of daily discharges, monthly means, and run-off to be made. For such computations form 9–192 has been prepared (see p. 45). Daily gage heights

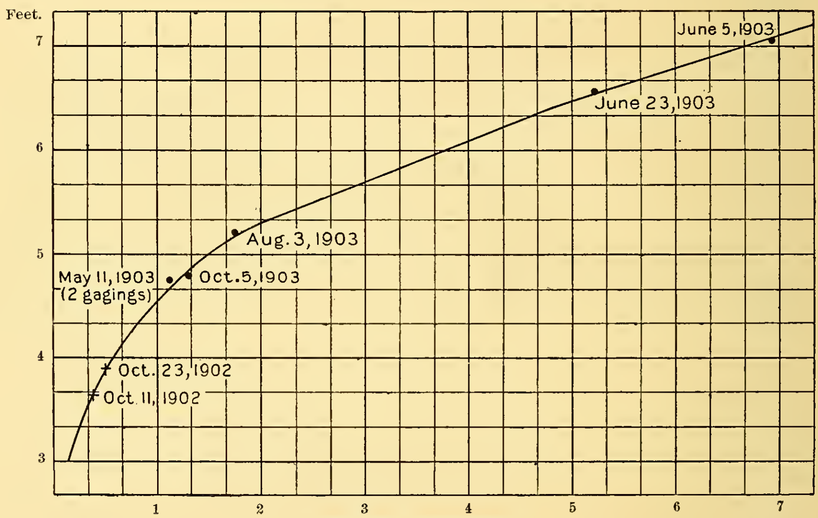


FIG. 7.—A good station-rating curve.

are copied from the gage-height cards as they are received from the hydrographer, and the corresponding discharge is taken from the rating table shown on page 44, which is made up from the curve shown in fig. 7. It is assumed that this discharge is the mean discharge in cubic feet for that day. The mean for each month is the mean of the average daily discharges in cubic feet per second. The run-off per square mile in second-feet (cubic feet per second) is obtained by dividing the mean monthly discharge by the number of square miles of drainage area; being a rate of flow it is independent of the number of days in the month. The run-off in inches is obtained from the run-off per square mile by the use of the table on pages 57–60. The run-off in acre-feet is obtained from the mean for the month by the use of

the table on pages 52–56. The maximum and minimum are the discharges for that day on which the mean discharge is the greatest or

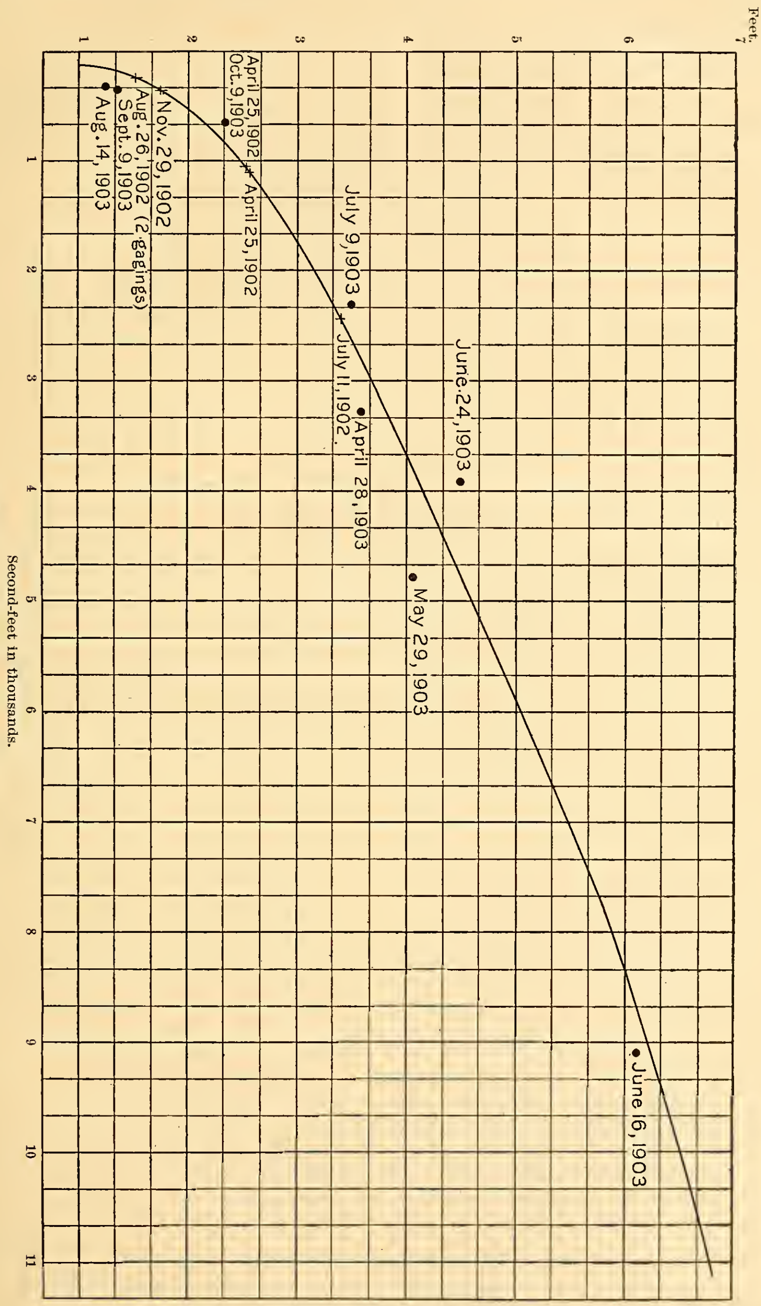


Fig. 8.—A poor station-rating curve.

least, respectively. When the daily discharge depends upon the mean of gage readings taken twice each day, the maximum or minimum

may not show the greatest or the least amount of water that was flowing in the river during the period covered by the records. They show the extreme discharges that may be considered as applicable to periods of twenty-four hours.

9–210.

Computed by F. H. B.
Checked by L. R. S.

DEPARTMENT OF THE INTERIOR.

UNITED STATES GEOLOGICAL SURVEY.

DIVISION OF HYDROGRAPHY.

RATING TABLE FOR STATION

For *Saint Mary* River at *International Line*. Constructed by *F. H. B.*, from discharge measurements number ——— to ———, as shown on accompanying blank form 9–207, and also from soundings made at intervening dates, as follows: ——— ———.

This table is applicable only from *September 3*, 190*2*, to *December 31*, 190*3*.

Gage height.	Discharge.	Difference.	Gage height.	Discharge.	Difference.	Gage height.	Discharge.	Difference.	Gage height.	Discharge.	Difference.
3.00	*150*		*4*.00	*575*	*35*	*5*.00	*1,510*	*65*	*6*.00	*3,800*	*130*
.05	*162*	*12*	.05	*610*	*35*	.05	*1,575*	*65*	.05	*3,930*	*130*
.10	*175*	*13*	.10	*645*	*37*	.10	*1,640*	*80*	.10	*4,060*	*130*
.15	*190*	*15*	.15	*682*	*38*	.15	*1,720*	*80*	.15	*4,190*	*130*
.20	*205*	*15*	.20	*720*	*40*	.20	*1,800*	*100*	.20	*4,320*	*130*
.25	*222*	*17*	.25	*760*	*40*	.25	*1,900*	*100*	.25	*4,450*	*130*
.30	*239*	*17*	.30	*800*	*40*	.30	*2,000*	*120*	.30	*4,580*	*130*
.35	*257*	*18*	.35	*840*	*40*	.35	*2,120*	*120*	.35	*4,710*	*130*
.40	*275*	*20*	.40	*880*	*42*	.40	*2,240*	*130*	.40	*4,840*	*140*
.45	*295*	*20*	.45	*922*	*43*	.45	*2,370*	*130*	.45	*4,980*	*140*
.50	*315*	*22*	.50	*965*	*47*	.50	*2,500*	*130*	.50	*5,120*	*150*
.55	*337*	*23*	.55	*1,012*	*48*	.55	*2,630*	*130*	.55	*5,270*	*150*
.60	*360*	*25*	.60	*1,060*	*52*	.60	*2,760*	*130*	.60	*5,420*	*160*
.65	*385*	*25*	.65	*1,112*	*53*	.65	*2,890*	*130*	.65	*5,580*	*160*
.70	*410*	*25*	.70	*1,165*	*55*	.70	*3,020*	*130*	.70	------	-----
.75	*435*	*25*	.75	*1,220*	*55*	.75	*3,150*	*130*	.75	------	-----
.80	*460*	*27*	.80	*1,275*	*57*	.80	*3,280*	*130*	.80	------	-----
.85	*487*	*28*	.85	*1,332*	*58*	.85	*3,410*	*130*	.85	------	-----
.90	*515*	*30*	.90	*1,390*	*60*	.90	*3,540*	*130*	.90	------	-----
.95	*545*	*30*	.95	*1,450*	*60*	.95	*3,670*	*130*	.95	------	-----

Remarks: *Lowest discharge measurement at gage height, 3.65 feet; highest measurement at gage height, 7.05 feet. Curve extended above and below these points. Tangent above gage height, 6.60 feet, with a difference of 160 per half tenth.*

9–192 DEPARTMENT OF THE INTERIOR. Computed by R. H. B. Checked by L. R. S.

UNITED STATES GEOLOGICAL SURVEY

DIVISION OF HYDROGRAPHY.

Daily mean gage height and discharge in second-feet of *St. Mary* River, *near International Line, Cardston, Alberta*, for 1903. Drainage area, *452* sq. miles.

Observer, *L. C. Shaw.*

Day.	January.		February.		March.		April.		May.		June.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1	4.65	1,112	4.40	880	4.70	1.165	5.70	3,020	4.40	880	6.45	4,980
2	4.60	1,060	4.30	800	4.60	1,060	5.55	2,630	4.40	880	6.80	6,060
3	4.50	965	4.25	760	4.68	1,144	5.25	1,900	4.45	922	7.00	6,700
4	4.60	1,060	4.35	840	4.70	1,165	5.10	1,640	4.60	1,060	7.00	6,700
5	4.65	1,112	4.35	840	4.60	1,060	5.00	1,510	4.60	1,060	7.05	6,860
6	4.60	1,060	4.50	965	4.50	965	5.00	1,510	4.70	1,165	7.05	6,860
7	4.30	800	4.40	880	4.55	1,012	4.90	1,390	4.80	1,275	7.05	6,860
8	4.50	965	4.40	880	4.58	1,042	4.80	1,275	4.85	1,332	7.15	7,180
9	4.40	880	4.35	840	4.60	1,060	4.85	1,332	4.80	1,275	7.00	6,700
10	4.35	840	4.35	840	4.50	965	4.50	965	4.80	1,275	7.00	6,700
11	4.20	720	4.45	922	4.48	948	4.25	760	4.80	1,275	6.90	6,380
12	4.30	800	4.40	880	4.35	840	3.80	460	4.80	1,275	6.80	6,060
13	4.30	800	3.70	410	4.60	1,060	3.60	360	4.95	1,450	6.90	6,380
14	4.45	922	4.40	880	4.80	1,275	3.63	375	4.90	1,390	6.90	6,380
15	4.50	965	4.3	800	4.80	1,275	3.90	515	5.00	1,510	6.85	6,220
16	4.50	965	4.65	1,112	5.00	1,510	4.50	965	5.10	1,640	6.80	6,060
17	4.25	760	4.55	1,012	4.90	1,390	4.55	1,012	5.30	2,000	7.00	6,700
18	4.05	610	4.60	1,060	4.70	1,165	4.60	1,060	5.30	2,000	6.95	6,540
19	4.10	645	4.65	1,112	4.65	1,112	4.50	965	5.40	2,240	6.90	6,380
20	4.00	575	4.50	965	4.70	1,165	4.40	880	5.40	2,240	6.90	6,380
21	4.10	645	4.55	1,012	4.70	1,165	4.30	800	5.40	2,240	6.80	6,060
22	4.20	720	4.65	1,112	4.60	1,060	4.35	840	5.30	2,000	6.70	5,740
23	4.00	575	4.60	1,060	4.68	1,144	4.35	840	5.40	2,240	6.55	5,270
24	4.25	760	4.70	1,165	4.60	1,060	4.30	800	5.45	2,370	6.55	5,270
25	4.30	800	4.63	1,091	4.60	1,060	4.45	922	5.45	2,370	6.40	4,840
26	4.20	720	4.00	575	4.70	1,165	4.50	965	5.70	3,020	6.40	4,840
27	4.30	800	4.45	922	4.80	1,275	4.40	880	5.95	3,670	6.40	4,840
28	4.55	1,012	4.70	1,165	4.83	1,309	4.40	880	5.75	3,150	6.65	5,580
29	4.60	1,060			5.70	3,020	4.40	880	5.60	2,760	6.85	6,220
30	4.60	1,060			5.80	3,280	4.35	840	5.70	3,020	6.70	5,740
31	4.50	965			5.75	3,150			5.75	3,150		
Total		26,733		25,780		41,066		33,171		58,134		183,480
Mean		862		921		1,325		1,106		1,875		6,116
Run-off in inches		1.907		2.038		2.931		2.447		4.148		13.531
Run-off per square mile		2.198		2.122		3.381		2.728		4.781		15.100
Acre-feet		53,002		51,150		81,471		65,812		115,290		363,927

Rules for rejecting redundant figures.—In reducing the number of significant figures, or the number of decimal places, by dropping the last figure, the following rules apply:

(a) When the figure in the place to be rejected is less than 5, drop it without changing the preceding figure. Example: 1,827.4 becomes 1,827.

(b) When the figure in the place to be rejected is greater that 5, drop it and increase the preceding figure by 1. Example: 1,827.6 becomes 1,828.

(c) When the figure in the place to be rejected is 5, and it is preceded by an even figure, drop the 5. Example: 1,828.5 becomes 1,828.

(d) When the figure in the place to be rejected is 5, and it is preceded by an odd figure, drop the 5 and increase the preceding odd figure by 1. Example: 1,827.5 becomes 1,828.

Units of measurement.—The volume flowing in a stream is usually expressed in cubic feet per second, briefly expressed as "second-feet." A second-foot may be defined as the body of water flowing in a stream 1 foot wide, 1 foot deep, at a rate of 1 foot per second.

There is in common use by miners and irrigators throughout the West another unit called the miners' inch. It is an indefinite quantity, but in most States is recognized as the fiftieth part of a second-foot.

The unit of capacity used in connection with storage is the acre-foot, and is equivalent to 43,560 cubic feet. It is a quantity that would cover an acre to a depth of 1 foot. There is a convenient relation between the second-foot and the acre-foot; one second-foot flowing for twenty-four hours will deliver 86,400 cubic feet, which equals 1.9835 acre-feet, or, approximately 2 acre-feet.

One million gallons is sometimes used as the unit of storage; there is a convenient relation between this unit and the acre-foot. One acre-foot equals 325,851.45 gallons, or somewhat less than one-third of a million gallons.

Computation of meter measurements.—Because of the fact that velocity is not constant in all parts of the cross section the quantity flowing through each square foot of the section is not the same, and it is necessary to divide the cross-section area into parts and compute the discharge through each part separately. The total discharge is then the sum of the discharge through all the parts. The size of these component parts depends on the rapidity of change of the velocity and the degree of accuracy required. For convenience these component parts are vertical strips, bounded on two sides by soundings.

Fig. 9 shows the cross section of the Saline River near Salina, Kans., on September 30, 1903, while the discharge measurement recorded on page 48 was being made. The soundings were taken at each 5 feet of width from the initial point and the velocity was observed at 0.6 depth below the surface in each of these verticals.

The discharge through each 5-foot strip might be computed separately, but the computations are shortened by finding the discharge through each double strip at a time. The mean depth and the mean velocity for the double strip of width 10 feet are found from the formula:

$$d'_m = \frac{a + 4b + c}{6} \quad (1); \qquad V'_m = \frac{V_a + 4V_b + V_c}{6} \quad (2)$$

The discharge through the double strip is:

$$Q' = d'_m V'_m 2L = \left(\frac{a + 4b + c}{6} 2L\right)\left(\frac{V_a + 4V_b + V_c}{6}\right) \quad (3)$$

Formulas (1) and (2) are based on the assumption that the stream bed is a series of parabolic arcs, also that the horizontal velocity curves

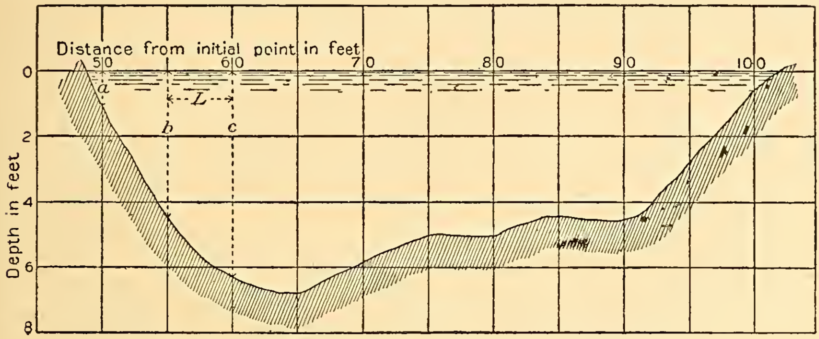


FIG. 9.—Cross section of Saline River at gaging station near Salina, Kans.

are parabolic arcs, both of which assumptions are approximately true at good current-meter stations.

d'_m = mean depth for double strip;
V'_m = mean velocity for double strip;
a, b, c are three consecutive depths, L feet apart;
V_a, V_b, V_c are observed velocities in the verticals, a, b, c;
L = the width of a single strip;
Q' = the discharge through double strip.

In computing the discharge and the mean depth through a single strip near the stream bank or a pier the mean velocity is found from the formulas:

$$V_m = \frac{V_o + V_a}{2}; \qquad d = \frac{a' + a}{2}$$

where either V_o or V_a and a' or a may be "0."

Velocity is computed to two places of decimals, mean depth, area, and discharge to one place of decimals for streams of ordinary size; for small streams with hard, smooth bottom, where the depth can be measured to hundredths foot, the mean depth and area should be computed to two places of decimals and the discharge to one place.

Gaging made *September 30*, 190*3*, by *E. C. Murphy*. Meter No. *388*, on *Saline* River near *Salina*, State of *Kansas*.

[Gage height: Beginning *7.96* ft., ending *7.96* ft., mean *7.96* feet. River *stationary*. Total area, *233* sq. feet. Mean velocity, *0.82*. Discharge, *190* second-feet.]

Dist. from initial point.	Observations.				Velocity computations.				Computations of—		Area of sec.	Discharge of section.	Remarks. (On condition of channel, wind, equipment, gage, boat, cable, methods, accuracy. Use cross-section pages in back of book for sketches.)
	Depth.	Depth of observat.	Time in seconds.	Revolutions.	Total number revolutions.	Revolutions per second.	Velocity per second.	Mean velocity per second.	Width.	Mean depth.			
49	*0.0*	......	......	....	......	......	*0.0*	*0.20*	*1*	*0.6*	*0.6*	*0.1*	Length of gage wire measured and found to *be 35.47 feet.* *Clear. No wind.*
50	*1.1*	*0.7*	*50*	*7 and 8*	*15*	......	*0.40*	......	......	......	......	......	
55	*4.5*	*2.7*	*50*	*16 and 17*	*33*	......	*0.82*	*0.79*	*10*	*4.2*	*42.0*	*33.2*	
60	*6.3*	*3.8*	*50*	*21 and 22*	*43*	......	*1.06*	......	......	......	......	......	
65	*6.8*	*4.1*	*50*	*19 and 18*	*37*	......	*0.92*	*0.95*	*10*	*6.6*	*66.0*	*62.7*	
70	*5.9*	*3.5*	*50*	*19 and 20*	*39*	......	*0.97*	......	......	......	......	......	
75	*5.0*	*3.0*	*50*	*23 and 24*	*47*	......	*1.15*	*1.11*	*10*	*5.2*	*52.0*	*57.7*	
80	*5.0*	*3.0*	*50*	*22 and 23*	*45*	......	*1.10*	......	......	......	......	......	
85	*4.4*	*2.6*	*50*	*14 and 15*	*29*	......	*0.73*	*0.73*	*10*	*4.5*	*45.0*	*32.9*	
90	*4.5*	*2.7*	*50*	*6 and 6*	*12*	......	*0.33*	......	......	......	......	......	
95	*2.8*	*1.7*	*50*	*0 and 0*	*0*	......	*0.00*	*0.17*	*5*	*3.6*	*18.0*	*3.1*	
100	*0.6*	*0.4*	*50*	*0 and 0*	*0*	......	*0.00*	*0.00*	*7*	*1.3*	*9.1*	*0.0*	
102	*0.0*	......	......	....	......	......	......	......	......	......	......	......	
......	......	......	......	....	......	......	......	......	......	......	*232.7*	*189.7*	

Computed by *E. C. Murphy*. Checked by *E. C. Murphy*.

If the district hydrographer desires he can compute discharge from the formula given on page eighty-six of "Instructions relating to the work of the United States Geological Survey, May 1, 1903," namely, (with altered symbols); $Q' = \left(\frac{a + 6b + c}{8}\right) LV_b$. The letters have the same meaning as in the formula on page 47, except that Q' is the discharge through the vertical section extending from halfway between a and b to halfway between b and c.

It sometimes happens that the velocity becomes very small or "0" in some parts of the cross-section at a station, as in the case of the Salina station for the part from 95 to 102 feet from the initial point. This area of small or "0" velocity is sometimes neglected in computing the cross-sectional area and the mean velocity. Mean velocity obtained in this way is sometimes misleading, because it may make a section in which the true velocity is only 0.3 or 0.4 foot per second (a section that should not be used) appear to have a velocity of half a foot or more per second. There is danger, too, that if this low velocity area is neglected in computing mean velocity, no attention will be given to measuring those velocities, and thus an error will be introduced into the discharge. It has been decided to include the whole area in the column headed "area" in computing mean velocity.

COMPUTATIONS OF VERTICAL-VELOCITY CURVES AND COEFFICIENTS.

The method of making vertical-velocity-curve observations is described on page 20, the form for recording the observations is given on page 50, the velocities in column 4 are plotted as shown on page 51, the depth of center of meter below the surface being used as ordinates and velocities as abscissas. A smooth curve is drawn among them making a graphic adjustment of the observations. The mean abscissa of this curve is the mean velocity in this vertical. The depth below the surface of the thread of mean velocity is the ordinate which corresponds to the mean abscissa or to the computed mean velocity.

To compute the mean velocity from the vertical-velocity curve, divide the depth into from 5 to 10 equal parts and write the velocity at the center of each part in column 6, headed "velocity from curve." Find the sum of these and divide by the number of parts; the quotient is the mean velocity in that vertical.

It is often more convenient, when the depth is a number of feet and a fraction, as 8.3 feet, to divide the depth into 8 parts of a foot width, and a part of 0.3 foot width. Then the velocity to enter in column 6 for the narrow part is 0.3 of the velocity at the center of it.

The velocities at a point 1 foot below the surface, mid-depth, and bottom are read directly from the vertical-velocity curve, and recorded in column 8. The "coefficients for reducing to mean velocity," required in column 9, are obtained by dividing the mean velocity by each of the velocities in column 8.

Vertical-velocity measurement made *November 2, 1903*, by E. C. Murphy, meter No.
585 feet from initial point

Gage height: beginning *3.08* ft., ending 3.08 ft.,

FIELD NOTES.				DATA FROM CURVE AND COMPUTATION.				
Depth of center of meter below surface in feet.	Number revolutions per *50* seconds.	Number revolutions per second.	Velocity per second.	Middle of horizontal section.	Velocity from curve.	Point in vertical.	Velocity.	Coefficient for reducing to mean velocity.
0.5	61–61 61–62	1.22	2.85	1	2.85	0.6 depth.	2.45	1.01
1.5	59 57	1.16	2.71	2	2.78	1 ft. below surface.	2.82	0.88
2.5	58 61	1.19	2.79	3	2.72	Bottom.	1.40	1.77
3.5	54 55	1.09	2.58	4	2.62	Mid depth.	2.57	0.96
4.5	57 54	1.11	2.60	5	2.50			
5.5	45 51	.96	2.25	6	2.35	Depth of mean velocity = { *4.5* ft., *56* per cent of depth.		
6.5	44 48	.92	2.16	7	2.16			
7.5	38 39	.77	1.82	8	1.82			
8.0				9				
				10				
				Total	19.80	Computed by *Brundage*.		
				Mean	2.48	Checked by *Marsh*.		

Fall of river, —— feet per mile.

Remarks.—(Wind conditions. Character of stream bed. Roughness under surface of ice, etc.)

338, on *Susquehanna* River, at *Harrisburg*, State of *Pennsylvania*. Measurements at for soundings. Depth *8* ft.

mean *3.08* ft. Channel *open*. Thickness of ice, —— ft.

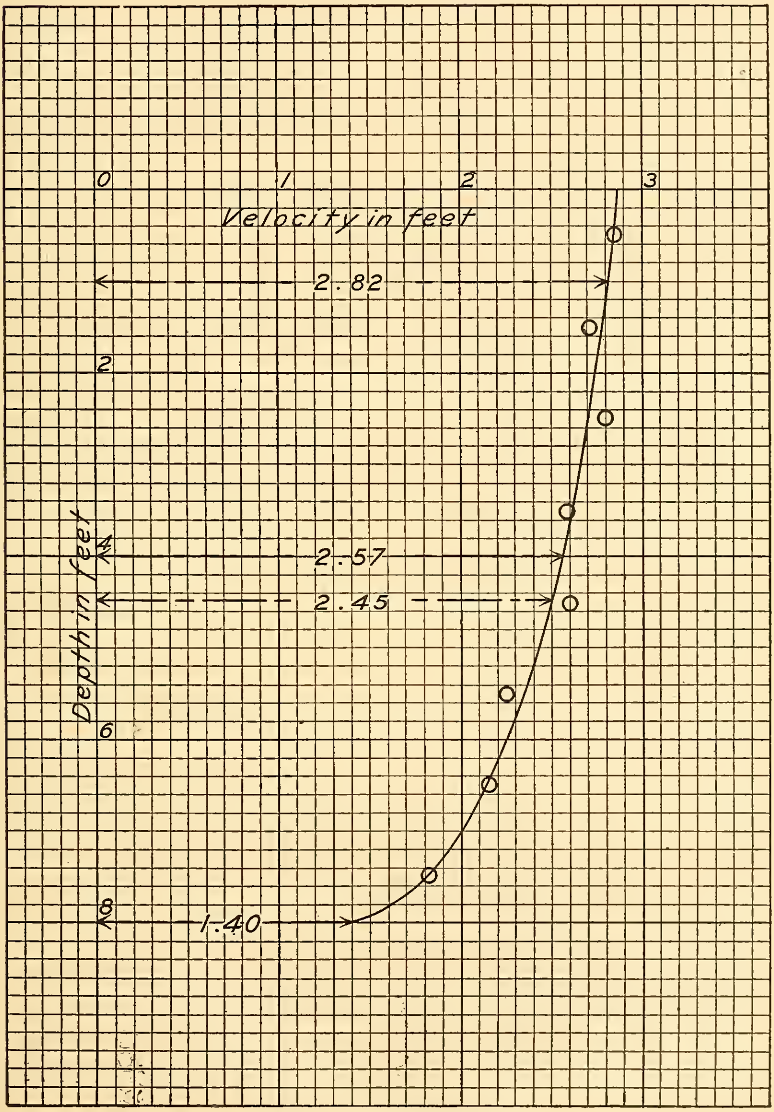


FIG. 10.—Vertical-velocity curve.

TABLES.

TABLES FOR COMPUTATION OF RUN-OFF.

Table for converting second-feet into acre-feet per day.

Days.	Second-feet.								
	1.	2.	3.	4.	5.	6.	7.	8.	9.
	Acre-ft.	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*
1	1.98	3.97	5.95	7.93	9.92	11.90	13.88	15.87	17.85
2	3.97	7.93	11.90	15.87	19.83	23.80	27.77	31.74	35.70
3	5.95	11.90	17.85	23.80	29.75	35.70	41.65	47.60	53.55
4	7.93	15.87	23.80	31.74	39.67	47.60	55.54	63.47	71.40
5	9.92	19.83	29.75	39.67	49.59	59.50	69.42	79.34	89.26
6	11.90	23.80	35.70	47.60	59.50	71.40	83.31	95.21	107.11
7	13.88	27.77	41.65	55.54	69.42	83.31	97.19	111.07	124.96
8	15.87	31.74	47.60	63.47	79.34	95.21	111.07	126.94	142.81
9	17.85	35.70	53.55	71.40	89.26	107.11	124.96	142.81	160.66
10	19.83	39.67	59.50	79.34	99.17	119.01	138.84	158.68	178.51
11	21.82	43.64	65.45	87.27	109.09	130.91	152.73	174.55	196.36
12	23.80	47.60	71.40	95.21	119.01	142.81	166.61	190.41	214.21
13	25.79	51.57	77.35	103.14	128.93	154.71	180.50	206.28	232.07
14	27.77	55.54	83.31	111.07	138.84	166.61	194.38	222.15	249.92
15	29.75	59.50	89.26	119.01	148.76	178.51	208.26	238.02	267.77
16	31.74	63.47	95.21	126.94	158.68	190.41	222.15	253.88	285.62
17	33.72	67.44	101.16	134.88	168.59	202.31	236.03	269.75	303.47
18	35.70	71.40	107.11	142.81	178.51	214.21	249.92	285.62	321.32
19	37.69	75.37	113.06	150.74	188.43	226.12	263.80	301.49	339.17
20	39.67	79.34	119.01	158.68	198.35	238.02	277.69	317.36	357.02
21	41.65	83.31	124.96	166.61	208.26	249.92	291.57	333.22	374.88
22	43.64	87.27	130.91	174.55	218.18	261.82	305.45	349.09	392.73
23	45.62	91.24	136.86	182.48	228.10	273.72	319.34	364.96	410.58
24	47.60	95.21	142.81	190.41	238.02	285.62	333.22	380.82	428.43
25	49.59	99.17	148.76	198.35	247.93	297.52	347.11	396.69	446.28
26	51.57	103.14	154.71	206.28	257.85	309.42	360.99	412.56	464.13
27	53.55	107.11	160.66	214.21	267.77	321.32	374.88	428.43	481.98
28	55.54	111.07	166.61	222.15	277.69	333.22	388.76	444.30	499.83
29	57.52	115.04	172.56	230.08	287.60	345.12	402.64	460.17	517.68
30	59.50	119.01	178.51	238.02	297.52	357.02	416.53	476.03	535.54
31	61.49	122.98	184.46	245.95	307.44	368.93	430.41	491.90	553.39

As the months are of varying length it is necessary to use three or four factors to convert the average discharge for the month in second-feet into the total in acre-feet. One second-foot flowing for twenty-four hours is equivalent to 86,400 cubic feet. Since there are 43,560 square feet in an acre there will be the same number of cubic feet in an acre-foot. Dividing, it is found that 1 second-foot for twenty-four hours very nearly equals 2 acre-feet, or, in exact figures, 1.983471 acre-feet. This multiplied by the number of days in the month will give the total monthly discharge in acre-feet. This quantity, therefore, must be multiplied by 28 for the month of February, or 29 for that month in leap year, and by 30 or 31 for the other months.

For the month of February when it has 28 days the factor to be used is 55.537188. For convenience in computation this factor multiplied from 1 to 9 is given in the following table:

1	55.53719
2	111.07438
3	166.61156
4	222.14875
5	277.68594
6	333.22313
7	388.76032
8	444.29750
9	499.83469

When February has 29 days the factor to be used is 57.520659. This when multiplied from 1 to 9 gives the following:

1	57.52066
2	115.04132
3	172.56198
4	230.08264
5	287.60330
6	345.12395
7	402.64461
8	460.16527
9	517.68593

For the months containing 30 days, viz, April, June, September, and November, the factor to be used is 59.504130. This, when multiplied by the unit figures, gives the following results:

1	59.50413
2	119.00826
3	178.51239
4	238.01652
5	297.52065
6	357.02478
7	416.52891
8	476.03304
9	535.53717

For the months containing 31 days, viz, January, March, May, July, August, October, and December, the factor to be used is 61.487601. This, when multiplied by the unit figures, gives the following results:

1	61.48760
2	122.97520
3	184.46280
4	245.95040
5	307.43800
6	368.92561
7	430.41321
8	491.90081
9	553.38841

Table for converting second-feet into acre-feet per month of twenty-eight days.

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0......	....	55.537	111.074	166.612	222.149	277.686	333.223	388.760	444.298	499.835
1......	555.372	610.909	666.446	721.983	777.521	833.058	888.595	944.132	999.669	1,055.206
2......	1,110.744	1,166.281	1,221.818	1,277.355	1,332.892	1,388.430	1,443.967	1,499.504	1,555.041	1,610.578
3......	1,666.116	1,721.653	1,777.190	1,832.727	1,888.264	1,943.802	1,999.339	2,054.876	2,110.413	2,165.950
4......	2,221.488	2,277.025	2,332.562	2,388.099	2,443.636	2,499.173	2,554.711	2,610.248	2,665.785	2,721.322
5......	2,776.859	2,832.396	2,887.934	2,943.471	2,999.008	3,054.545	3,110.082	3,165.620	3,221.157	3,276.694
6......	3,332.231	3,387.768	3,443.306	3,498.843	3,554.380	3,609.917	3,665.454	3,720.992	3,776.529	3,832.066
7......	3,887.603	3,943.140	3,998.678	4,054.215	4,109.752	4,165.289	4,220.826	4,276.363	4,331.901	4,387.438
8......	4,442.975	4,498.512	4,554.049	4,609.587	4,665.124	4,720.661	4,776.198	4,831.735	4,887.272	4,942.810
9......	4,998.347	5,053.884	5,109.421	5,164.958	5,220.496	5,276.033	5,331.570	5,387.107	5,442.644	5,498.182
10......	5,553.719	5,609.256	5,664.793	5,720.330	5,775.868	5,831.405	5,886.942	5,942.479	5,998.016	6,053.553

Table for converting second-feet into acre-feet per month of twenty-nine days.

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0......	....	57.521	115.041	172.562	230.083	287.603	345.124	402.645	460.165	517.686
1......	575.207	632.727	690.248	747.768	805.289	862.810	920.330	977.851	1,035.372	1,092.892
2......	1,150.413	1,207.934	1,265.454	1,322.975	1,380.496	1,438.016	1,495.537	1,553.058	1,610.578	1,668.099
3......	1,725.620	1,783.140	1,840.661	1,898.182	1,955.702	2,013.223	2,070.744	2,128.264	2,185.785	2,243.306
4......	2,300.826	2,358.347	2,415.868	2,473.388	2,530.909	2,588.430	2,645.950	2,703.471	2,760.992	2,818.512
5......	2,876.033	2,933.554	2,991.074	3,048.595	3,106.116	3,163.636	3,221.157	3,278.678	3,336.198	3,393.719
6......	3,451.240	3,508.760	3,566.281	3,623.802	3,681.322	3,738.843	3,796.363	3,853.884	3,911.405	3,968.925

7......	4, 026. 446	4, 083. 967	4, 141. 487	4, 199. 008	4, 256. 529	4, 314. 049	4, 371. 570	4, 429. 091	4, 486. 611	4, 544. 132
8......	4, 601. 653	4, 659. 173	4, 716. 694	4, 774. 215	4, 831. 735	4, 889. 256	4, 946. 777	5, 004. 297	5, 061. 818	5, 119. 339
9......	5, 176. 859	5, 234. 380	5, 291. 901	5, 349. 421	5, 406. 942	5, 464. 463	5, 521. 983	5, 579. 504	5, 637. 024	5, 694. 545
10......	5, 752. 066	5, 809. 586	5, 867. 107	5, 924. 628	5, 982. 148	6, 039. 669	6, 097. 190	6, 154. 710	6, 212. 231	6, 269. 752

Table for converting second-feet into acre-feet per month of thirty days.

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0......	....	59. 504	119. 008	178. 512	238. 016	297. 521	357. 025	416. 529	476. 033	535. 537
1......	595. 041	654. 545	714. 050	773. 554	833. 058	892. 562	952. 066	1, 011. 570	1, 071. 074	1, 130. 578
2......	1, 190. 083	1, 249. 587	1, 309. 091	1, 368. 595	1, 428. 099	1, 487. 603	1, 547. 107	1, 606. 612	1, 666. 116	1, 725. 620
3......	1, 785. 124	1, 844. 628	1, 904. 132	1, 963. 636	2, 023. 140	2, 082. 644	2, 142. 149	2, 201. 653	2, 261. 157	2, 320. 661
4......	2, 380. 165	2, 439. 669	2, 499. 173	2, 558. 678	2, 618. 182	2, 677. 686	2, 737. 190	2, 796. 694	2, 856. 198	2, 915. 702
5......	2, 975. 206	3, 034. 711	3, 094. 215	3, 153. 719	3, 213. 223	3, 272. 727	3, 332. 231	3, 391. 735	3, 451. 240	3, 510. 744
6......	3, 570. 248	3, 629. 752	3, 689. 256	3, 748. 760	3, 808. 264	3, 867. 768	3, 927. 272	3, 986. 777	4, 046. 281	4, 105. 785
7......	4, 165. 289	4, 224. 793	4, 284. 297	4, 343. 801	4, 403. 306	4, 462. 810	4, 522. 314	4, 581. 818	4, 641. 322	4, 700. 826
8......	4, 760. 330	4, 819. 834	4, 879. 339	4, 938. 843	4, 998. 347	5, 057. 851	5, 117. 355	5, 176. 859	5, 236. 363	5, 295. 868
9......	5, 355. 372	5, 414. 876	5, 474. 380	5, 533. 884	5, 593. 388	5, 652. 892	5, 712. 396	5, 771. 901	5, 831. 405	5, 890. 909
10......	5, 950. 413	6, 009. 917	6, 069. 421	6, 128. 925	6, 188. 430	6, 247. 934	6, 307. 438	6, 366. 942	6, 426. 446	6, 485. 950

Table for converting second-feet into acre-feet per month of thirty-one days.

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	....	61.488	122.975	184.463	245.950	307.438	368.926	430.413	491.901	553.388
1	614.876	676.364	737.851	799.339	860.826	922.314	983.802	1,045.289	1,106.777	1,168.264
2	1,229.752	1,291.240	1,352.727	1,414.215	1,475.702	1,537.190	1,598.678	1,660.165	1,721.653	1,783.140
3	1,844.628	1,906.116	1,967.603	2,029.091	2,090.578	2,152.066	2,213.554	2,275.041	2,336.529	2,398.016
4	2,459.504	2,520.992	2,582.479	2,643.967	2,705.454	2,766.942	2,828.430	2,889.917	2,951.405	3,012.892
5	3,074.380	3,135.868	3,197.355	3,258.843	3,320.330	3,381.818	3,443.306	3,504.793	3,566.281	3,627.768
6	3,689.256	3,750.744	3,812.231	3,873.719	3,935.206	3,996.694	4,058.182	4,119.669	4,181.157	4,242.644
7	4,304.132	4,365.620	4,427.107	4,488.595	4,550.082	4,611.570	4,673.058	4,734.545	4,796.033	4,857.520
8	4,919.008	4,980.496	5,041.983	5,103.471	5,164.958	5,226.446	5,287.934	5,349.421	5,410.909	5,472.396
9	5,533.884	5,595.372	5,656.859	5,718.347	5,779.834	5,841.322	5,902.810	5,964.297	6,025.785	6,087.272
10	6,148.760	6,210.248	6,271.735	6,333.223	6,394.710	6,456.198	6,517.686	6,579.173	6,640.661	6,702.148

The depth of run-off over the drainage basin is usually computed in inches for convenience of comparison with the depth of rainfall, which is almost invariably given in that unit. This depth can most conveniently be computed from the run-off per square mile by computation based upon the number of days in each month and the relation between the rate of flow and the depth in inches for this quantity were it held during the given number of days. One second-foot for twenty-four hours is equivalent to 86,400 cubic feet in one day. In other words, 1 cubic foot per second run-off from 1 square mile would, if held upon this area, cover it to a depth represented by dividing 86,400 by the number of square feet in a mile, 27,878,400, or 5,280 squared. Completing this division, it is found that 1 second-foot for one day is equivalent to a body of water covering 1 square mile 0.003099174 feet, or 0.037190088 inch. Multiplying this by the number of days in a month gives the following factors:

28 days	1.041322528
29 days	1.078512604
30 days	1.115702680
31 days	1.152892756

Table for converting run-off in second-feet per square mile into depth in inches per month of twenty-eight days.

	0.0.	0.1.	0.2.	0.3.	0.4.	0.5.	0.6.	0.7.	0.8.	0.9.
1......	1.0413	1.1454	1.2496	1.3537	1.4578	1.5620	1.6661	1.7702	1.8744	1.9785
2......	2.0826	2.1868	2.2909	2.3950	2.4992	2.6033	2.7074	2.8116	2.9157	3.0198
3......	3.1240	3.2281	3.3322	3.4364	3.5405	3.6446	3.7488	3.8529	3.9570	4.0612
4......	4.1653	4.2694	4.3736	4.4777	4.5818	4.6859	4.7901	4.8942	4.9983	5.1025
5......	5.2066	5.3107	5.4149	5.5190	5.6231	5.7273	5.8314	5.9355	6.0397	6.1438
6......	6.2479	6.3521	6.4562	6.5603	6.6645	6.7686	6.8727	6.9769	7.0810	7.1851
7......	7.2892	7.3934	7.4975	7.6016	7.7058	7.8100	7.9140	8.0182	8.1223	8.2264
8......	8.3306	8.4347	8.5388	8.6430	8.7471	8.8512	8.9554	9.0595	9.1636	9.2678
9......	9.3719	9.4760	9.5802	9.6843	9.7884	9.8926	9.9967	10.1008	10.2050	10.3091
10......	10.4132	10.5174	10.6215	10.7256	10.8297	10.9339	11.0380	11.1421	11.2463	11.3504

Table for converting run-off in second-feet per square mile into depth in inches per month of twenty-nine days.

	0.0.	0.1.	0.2.	0.3.	0.4.	0.5.	0.6.	0.7.	0.8.	0.9.
1......	1.0785	1.1864	1.2942	1.4021	1.5099	1.6178	1.7256	1.8335	1.9413	2.0492
2......	2.1570	2.2649	2.3727	2.4806	2.5884	2.6963	2.8041	2.9120	3.0198	3.1277
3......	3.2355	3.3434	3.4512	3.5591	3.6669	3.7748	3.8826	3.9905	4.0983	4.2062
4......	4.3140	4.4219	4.5298	4.6376	4.7454	4.8533	4.9612	5.0690	5.1768	5.2847
5......	5.3926	5.5004	5.6083	5.7161	5.8240	5.9318	6.0397	6.1475	6.2554	6.3632
6......	6.4711	6.5789	6.6868	6.7946	6.9025	7.0103	7.1182	7.2260	7.3339	7.4417
7......	7.5496	7.6574	7.7653	7.8731	7.9810	8.0888	8.1967	8.3045	8.4124	8.5202

8......	8.6281	8.7359	8.8438	8.9516	9.0595	9.1674	9.2752	9.3830	9.4909	9.5988
9......	9.7066	9.8145	9.9223	10.0302	10.1380	10.2459	10.3537	10.4616	10.5694	10.6773
10......	10.7851	10.8930	11.0008	11.1087	11.2165	11.3244	11.4322	11.5401	11.6479	11.7558

Table for converting run-off in second-feet per square mile into depth in inches per month of thirty days.

	0.0.	0.1.	0.2.	0.3.	0.4.	0.5.	0.6.	0.7.	0.8.	0.9.
1......	1.1157	1.2273	1.3388	1.4504	1.5620	1.6736	1.7851	1.8967	2.0083	2.1198
2......	2.2314	2.3430	2.4545	2.5661	2.6777	2.7893	2.9008	3.0124	3.1240	3.2355
3......	3.3471	3.4587	3.5702	3.6818	3.7934	3.9050	4.0165	4.1281	4.2397	4.3512
4......	4.4628	4.5744	4.6859	4.7975	4.9091	5.0207	5.1322	5.2438	5.3554	5.4669
5......	5.5785	5.6901	5.8016	5.9132	6.0248	6.1364	6.2479	6.3595	6.4711	6.5826
6......	6.6942	6.8058	6.9174	7.0289	7.1405	7.2521	7.3636	7.4752	7.5868	7.6983
7......	7.8099	7.9215	8.0330	8.1446	8.2562	8.3678	8.4793	8.5909	8.7025	8.8140
8......	8.9256	9.0372	9.1488	9.2603	9.3719	9.4835	9.5950	9.7066	9.8182	9.9298
9......	10.0413	10.1529	10.2645	10.3760	10.4876	10.5992	10.7107	10.8223	10.9339	11.0454
10......	11.1570	11.2686	11.3802	11.4917	11.6033	11.7149	11.8264	11.9380	12.0496	12.1612

Table for converting run-off in second-feet per square mile into depth in inches per month of thirty-one days.

	0.0.	0.1.	0.2.	0.3.	0.4.	0.5.	0.6.	0.7.	0.8.	0.9.
1......	1.1529	1.2682	1.3835	1.4988	1.6140	1.7293	1.8446	1.9599	2.0752	2.1905
2......	2.3058	2.4211	2.5364	2.6516	2.7669	2.8822	2.9975	3.1128	3.2281	3.3434
3......	3.4587	3.5740	3.6892	3.8045	3.9198	4.0351	4.1504	4.2657	4.3810	4.4963
4......	4.6116	4.7268	4.8421	4.9574	5.0727	5.1880	5.3033	5.4186	5.5339	5.6492
5......	5.7645	5.8798	5.9950	6.1103	6.2256	6.3409	6.4562	6.5715	6.6868	6.8021
6......	6.9174	7.0326	7.1479	7.2632	7.3785	7.4938	7.6091	7.7244	7.8397	7.9550
7......	8.0702	8.1855	8.3008	8.4161	8.5314	8.6467	8.7620	8.8773	8.9926	9.1078
8......	9.2231	9.3384	9.4537	9.5690	9.6843	9.7996	9.9149	10.0302	10.1454	10.2607
9......	10.3760	10.4913	10.6066	10.7219	10.8372	10.9525	11.0678	11.1830	11.2983	11.4136
10......	11.5289	11.6442	11.7595	11.8748	11.9901	12.1054	12.2206	12.3359	12.4512	12.5665

MISCELLANEOUS TABLES.

Cubic feet into gallons.

1 cubic foot=1,728 cubic inches=$\frac{1,728}{231}$gallons=7.4805194 gallons.

[In gallons.]

1 cubic foot	7.4805194
2 cubic feet	14.9610388
3 cubic feet	22.4415582
4 cubic feet	29.9220776
5 cubic feet	37.4025970
6 cubic feet	44.8831164
7 cubic feet	52.3636358
8 cubic feet	59.8441552
9 cubic feet	67.3246746

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	....	7.48	14.96	22.44	29.92	37.40	44.88	52.36	59.84	67.32
1	74.81	82.28	89.77	97.25	104.73	112.21	119.69	127.17	134.65	142.13
2	149.61	157.09	164.57	172.05	179.53	187.01	194.49	201.97	209.45	216.94
3	224.42	231.90	239.38	246.86	254.34	261.82	269.30	276.78	284.26	291.74
4	299.22	306.70	314.18	321.66	329.14	336.62	344.10	351.58	359.06	366.55
5	374.03	381.51	388.99	396.47	403.95	411.43	418.91	426.39	433.87	441.35
6	448.83	456.31	463.79	471.27	478.75	486.23	493.71	501.19	508.68	516.16
7	523.64	531.12	538.60	546.08	553.56	561.04	568.52	576.00	583.48	590.96
8	598.44	605.92	613.40	620.88	628.36	635.84	643.32	650.81	658.29	665.77
9	673.25	680.73	688.21	695.69	703.17	710.65	718.13	725.61	733.09	740.57

Gallons into cubic feet.

1 United States liquid gallon=231 cubic inches=$\frac{231}{1,728}$cubic foot=0.133680555 cubic feet.

[In cubic feet.]

1 gallon	0.13368055
2 gallons	.26736110
3 gallons	.40104165
4 gallons	.53472220
5 gallons	.66840275
6 gallons	0.80208330
7 gallons	.93576385
8 gallons	1.06944440
9 gallons	1.20312495

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	....	0.1337	0.2674	0.4010	0.5347	0.6684	0.8021	0.9358	1.0694	1.2031
1	1.3368	1.4705	1.6042	1.7378	1.8715	2.0052	2.1389	2.2726	2.4062	2.5399
2	2.6736	2.8073	2.9410	3.0746	3.2083	3.3420	3.4757	3.6094	3.7430	3.8767
3	4.0104	4.1441	4.2778	4.4114	4.5451	4.6788	4.8125	4.9462	5.0799	5.2135
4	5.3472	5.4809	5.6146	5.7483	5.8819	6.0156	6.1493	6.2830	6.4167	6.5503
5	6.6840	6.8177	6.9514	7.0851	7.2187	7.3524	7.4861	7.6198	7.7535	7.8872
6	8.0208	8.1545	8.2882	8.4219	8.5556	8.6892	8.8229	8.9566	9.0901	9.2240
7	9.3576	9.4913	9.6250	9.7587	9.8924	10.0260	10.1597	10.2934	10.4271	10.5608
8	10.6944	10.8281	10.9618	11.0955	11.2292	11.3628	11.4965	11.6302	11.7639	11.8976
9	12.0312	12.1649	12.2986	12.4323	12.5660	12.6996	12.8333	12.9670	13.1007	13.2344

Feet per second into miles per hour.

1 foot per second=3,600 feet per hour=$\frac{3,600}{5,280}$ or $\frac{15}{22}$ miles per hour=0.681828.

[In miles per hour.]

1 foot per second	0.68182
2 feet per second	1.36364
3 feet per second	2.04545
4 feet per second	2.72727
5 feet per second	3.40909
6 feet per second	4.09091
7 feet per second	4.77273
8 feet per second	5.45455
7 feet per second	6.13636

(See Smithsonian Meteorological Tables, No. 52.)

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	....	0.6818	1.3636	2.0455	2.7273	3.4091	4.0909	4.7727	5.4546	6.1364
1	6.8182	7.5000	8.1818	8.8637	9.5455	10.2273	10.9091	11.5909	12.2728	12.9546
2	13.6364	14.3182	15.0000	15.6819	16.3637	17.0455	17.7273	18.4091	19.0910	19.7728
3	20.4546	21.1364	21.8182	22.5001	23.1819	23.8637	24.5455	25.2273	25.9092	26.5910
4	27.2728	27.9546	28.6364	29.3183	30.0001	30.6819	31.3637	32.0455	32.7274	33.4092
5	34.0910	34.7728	35.4546	36.1365	36.8183	37.5001	38.1819	38.8637	39.5456	40.2274
6	40.9092	41.5910	42.2728	42.9547	43.6365	44.3183	45.0001	45.6819	46.3638	47.0456
7	47.7274	48.4092	49.0910	49.7729	50.4547	51.1365	51.8183	52.5001	53.1820	53.8638
8	54.5456	55.2274	55.9092	56.5911	57.2729	57.9547	58.6365	59.3183	60.0002	60.6820
9	61.3638	62.0456	62.7274	63.4093	64.0911	64.7729	65.4547	66.1365	66.8184	67.5002

Miles per hour into feet per second.

1 mile per hour=5,280 feet per hour=$\frac{5,280}{3,600}$ or $\frac{22}{15}$ feet per second=1.46667.

[In feet per second.]

1 mile per hour	1.46667
2 miles per hour	2.93333
3 miles per hour	4.40000
4 miles per hour	5.86667
5 miles per hour	7.33333
6 miles per hour	8.80000
7 miles per hour	10.26667
8 miles per hour	11.73333
9 miles per hour	13.20000

(See Smithsonian Meteorological Tables, No 51.)

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	....	1.4667	2.9333	4.4000	5.8667	7.3333	8.8000	10.2667	11.7333	13.2000
1	14.6667	16.1333	17.6000	19.0667	20.5333	22.0000	23.4667	24.9333	26.4000	27.8667
2	29.3333	30.8000	32.2667	33.7333	35.2000	36.6667	38.1333	39.6000	41.0667	42.5333
3	44.0000	45.4667	46.9333	48.4000	49.8667	51.3333	52.8000	54.2667	55.7333	57.2000
4	58.6667	60.1333	61.6000	63.0667	64.5333	66.0000	67.4667	68.9333	70.4000	71.8667
5	73.3333	74.8000	76.2667	77.7333	79.2000	80.6667	82.1333	83.6000	85.0667	86.5333
6	88.0000	89.4667	90.9333	92.4000	93.8667	95.3333	96.8000	98.2667	99.7333	101.2000
7	102.6667	104.1333	105.6000	107.0667	108.5333	110.0000	111.4667	112.9333	114.4000	115.8667
8	117.3333	118.8000	120.2667	121.7333	123.2000	124.6667	126.1333	127.6000	129.0667	130.5333
9	132.0000	133.4667	134.9333	136.4000	137.8667	139.3333	140.8000	142.2667	143.7333	145.2000

Second-feet per day into millions of gallons.

1 second-foot, or 7.4805194 gallons per second for 1 day, or 86,400 seconds=646,316.87616 gallons.

[In gallons.]

1 second-foot for 24 hours	646, 316.87	6 second-feet for 24 hours	3, 877, 901.26
2 second-feet for 24 hours	1, 292, 633.75	7 second-feet for 24 hours	4, 524, 218.13
3 second-feet for 24 hours	1, 938, 950.63	8 second-feet for 24 hours	5, 170, 535.01
4 second-feet for 24 hours	2, 585, 267.50	9 second-feet for 24 hours	5, 816, 851.88
5 second-feet for 24 hours	3, 231, 584.38		

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	....	0.6463	1.2926	1.9390	2.5853	3.2316	3.8779	4.5242	5.1705	5.8169
1	6.4632	7.1095	7.7558	8.4021	9.0484	9.6948	10.3411	10.9874	11.6337	12.2800
2	12.9263	13.5726	14.2190	14.8653	15.5116	16.1579	16.8042	17.4506	18.0969	18.7432
3	19.3895	20.0358	20.6821	21.3285	21.9748	22.6211	23.2674	23.9137	24.5600	25.2084
4	25.8527	26.4990	27.1453	27.7916	28.4379	29.0843	29.7306	30.3769	31.0232	31.6695
5	32.3158	32.9622	33.6085	34.2548	34.9011	35.5474	36.1937	36.8401	37.4864	38.1327
6	38.7790	39.4253	40.0716	40.7180	41.3643	42.0106	42.6569	43.3032	43.9495	44.5959
7	45.2422	45.8885	46.5348	47.1811	47.8274	48.4738	49.1201	49.7664	50.4127	51.0590
8	51.7054	52.3517	52.9980	53.6443	54.2906	54.9369	55.5833	56.2296	56.8759	57.5222
9	58.1685	58.8148	59.4612	60.1075	60.7538	61.4001	62.0464	62.6927	63.3391	63.9854

Millions of gallons into second-feet per day.

1 million gallons per 24 hours$=\frac{231{,}000{,}000}{1728\times 86400}$ cubic feet per second, or 1.5472286 second-feet.

[In second-feet per 24 hours.]

1 million gallons	1.5472286	6 million gallons	9.2833716
2 million gallons	3.0944572	7 million gallons	10.8306002
3 million gallons	4.6416858	8 million gallons	12.3778288
4 million gallons	6.1889144	9 million gallons	13.9250574
5 million gallons	7.7361430		

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	....	1.5472	3.0945	4.6417	6.1889	7.7361	9.2834	10.8306	12.3778	13.9251
1	15.4723	17.0195	18.5667	20.1140	21.6612	23.2084	24.7556	26.3029	27.8501	29.3973
2	30.9446	32.4918	34.0390	35.5862	37.1335	38.6807	40.2279	41.7752	43.3224	44.8696
3	46.4169	47.9641	49.5113	51.0585	52.6058	54.1530	55.7002	57.2474	58.7947	60.3419
4	61.8891	63.4364	64.9836	66.5308	68.0781	69.6253	71.1725	72.7197	74.2670	75.8142
5	77.3614	78.9087	80.4559	82.0031	83.5503	85.0976	86.6448	88.1920	89.7393	91.2865
6	92.8337	94.3809	95.9282	97.4754	99.0226	100.5699	102.1171	103.6643	105.2115	106.7588
7	108.3060	109.8532	111.4005	112.9477	114.4949	116.0421	117.5894	119.1366	120.6838	122.2311
8	123.7783	125.3255	126.8727	128.4200	129.9672	131.5144	133.0617	134.6089	136.1561	137.7033
9	139.2506	140.7978	142.3450	143.8923	145.4395	146.9867	148.5339	150.0812	151.6284	153.1756

Second-feet per day into acre-feet.

1 second-foot flow for one day=86,400 cubic feet=$\frac{86,400}{43,560}$, or 1.983471 acre-feet.

[In acre-feet.]

1 second-foot for 24 hours	1.98347
2 second-feet for 24 hours	3.96694
3 second-feet for 24 hours	5.95041
4 second-feet for 24 hours	7.93388
5 second-feet for 24 hours	9.91735
6 second-feet for 24 hours	11.90083
7 second-feet for 24 hours	13.88430
8 second-feet for 24 hours	15.86777
9 second-feet for 24 hours	17.85124

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	....	1.983	3.967	5.950	7.934	9.917	11.901	13.884	15.868	17.851
1	19.835	21.818	23.802	25.785	27.769	29.752	31.736	33.719	35.702	37.686
2	39.669	41.653	43.636	45.620	47.603	49.587	51.570	53.554	55.537	57.521
3	59.504	61.488	63.471	65.455	67.438	69.421	71.405	73.388	75.372	77.355
4	79.339	81.322	83.306	85.289	87.273	89.256	91.240	93.223	95.207	97.190
5	99.174	101.157	103.140	105.124	107.107	109.091	111.074	113.058	115.041	117.025
6	119.008	120.992	122.975	124.959	126.942	128.926	130.909	132.892	134.876	136.859
7	138.843	140.826	142.810	144.793	146.777	148.760	150.744	152.728	154.711	156.794
8	158.678	160.661	162.645	164.628	166.611	168.595	170.578	172.562	174.545	176.529
9	178.512	180.496	182.479	184.463	186.446	188.430	190.413	192.397	194.380	196.364

Acre-feet into second-feet flow for 24 hours.

1 acre-foot each 24 hours=43,560 cubic feet each 86,400 seconds=$\frac{43,560}{86,400}$, or $\frac{121}{240}$ second-foot flow for 24 hours = 0.50416666 +.

[In second-feet for 24 hours.]

1 acre-foot	0.50417
2 acre-feet	1.00833
3 acre-feet	1.51250
4 acre-feet	2.01667
5 acre-feet	2.52084
6 acre-feet	3.02500
7 acre-feet	3.52917
8 acre-feet	4.03334
9 acre-feet	4.53750

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	....	0.504	1.008	1.513	2.017	2.521	3.025	3.529	4.033	4.538
1	5.042	5.546	6.050	6.554	7.058	7.563	8.067	8.571	9.075	9.579
2	10.083	10.588	11.092	11.596	12.100	12.604	13.108	13.613	14.117	14.621
3	15.125	15.629	16.133	16.638	17.142	17.646	18.150	18.654	19.158	19.663
4	20.167	20.671	21.175	21.679	22.183	22.688	23.192	23.696	24.200	24.704
5	25.209	25.713	26.217	26.721	27.225	27.729	28.234	28.738	29.242	29.746
6	30.250	30.754	31.259	31.763	32.267	32.771	33.275	33.779	34.284	34.788
7	35.292	35.796	36.300	36.804	37.309	37.813	38.317	38.821	39.325	39.829
8	40.334	40.838	41.342	41.846	42.350	42.854	43.359	43.863	44.367	44.871
9	45.375	45.880	46.384	46.888	47.392	47.896	48.400	48.905	49.409	49.913

Acre-feet into millions of gallons.

1 acre-foot=43,560 cubic feet=$\frac{43,560\times 1,728}{231}$, or $\frac{75,271,680}{231}$, or 325,851.428 gallons.

[In gallons.]

	Millions.	Thousands.
1 acre-foot	0.325851428	325.9
2 acre-feet	.65170286	651.7
3 acre-feet	.97755429	977.6
4 acre-feet	1.30340572	1,303.4
5 acre-feet	1.62925715	1,629.3
6 acre-feet	1.95510858	1,955.1
7 acre-feet	2.28096001	2,281.0
8 acre-feet	2.60681144	2,606.8
9 acre-feet	2.93266287	2,932.7

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	....	0.3259	0.6517	0.9776	1.3034	1.6293	1.9551	2.2810	2.6068	2.9327
1	3.2585	3.5844	3.9102	4.2361	4.5619	4.8878	5.2136	5.5395	5.8653	6.1912
2	6.5170	5.8429	7.1687	7.4946	7.8204	8.1463	8.4721	8.7980	9.1238	9.4497
3	9.7755	10.1014	10.4272	10.7531	11.0789	11.4048	11.7306	12.0565	12.3823	12.7082
4	13.0341	13.3599	13.6857	14.0116	14.3374	14.6633	14.9891	15.3150	15.6408	15.9667
5	16.2926	16.6184	16.9443	17.2701	17.5960	17.9218	18.2477	18.5735	18.8994	19.2252
6	19.5511	19.8769	20.2028	20.5286	20.8545	21.1803	21.5062	21.8320	22.1579	22.4837
7	22.8096	23.1354	23.4613	23.7871	24.1130	24.4388	24.7647	25.0905	25.4164	25.7422
8	26.0681	26.3939	26.7198	27.0456	27.3715	27.6973	28.0232	28.3490	28.6749	29.0007
9	29.3266	29.6524	29.9783	30.3041	30.6300	30.9558	31.2817	31.6075	31.9334	32.2592

Millions of gallons into acre-feet.

One million United States liquid gallons or 231 million cubic inches = 133,680,555 cubic feet, or $\frac{133,680}{43,560}$=3.0688832 acre-feet.

[In acre-feet.]

1 million gallons	3.0688832
2 million gallons	6.1377664
3 million gallons	9.2066496
4 million gallons	12.2755328
5 million gallons	15.3444160
6 million gallons	18.4132992
7 million gallons	21.4821824
8 million gallons	24.5510656
9 million gallons	27.6199488

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	....	3.069	6.138	9.207	12.276	15.344	18.413	21.[illegible]82	24.551	27.620
1	30.689	33.758	36.827	39.895	42.964	46.033	49.102	52.171	55.240	58.309
2	61.378	64.446	67.515	70.584	73.653	76.722	79.791	82.860	85.929	88.998
3	92.066	95.135	98.204	101.273	104.342	107.411	110.480	113.549	116.618	119.686
4	122.755	125.824	128.893	131.962	135.031	138.100	141.169	144.238	147.306	150.375
5	153.444	156.513	159.582	162.651	165.720	168.789	171.857	174.926	177.995	181.064
6	184.133	187.202	190.271	193.340	196.409	199.477	202.546	205.615	208.684	211.753
7	214.822	217.891	220.960	224.028	227.097	230.166	233.235	236.304	239.373	242.442
8	245.511	248.580	251.648	254.717	257.786	260.855	263.924	266.993	270.062	273.131
9	276.199	279.268	282.337	285.406	288.475	291.544	294.613	297.682	300.751	303.819

Second-feet into minute-gallons.

Factors: 1 cubic foot contains 1,728 cubic inches; 1 gallon has a capacity of 231 cubic inches; 1 second-foot equals [(1,728 ÷ 231) × 60] gallons per minute, or 448.831164 minute-gallons.

[In gallons per minute.]

1 second-foot	448.831164	6 second-feet	2,692.986984
2 second-feet	897.662328	7 second-feet	3,141.818148
3 second-feet	1,346.493492	8 second-feet	3,590.649312
4 second-feet	1,795.324656	9 second-feet	4,039.480476
5 second-feet	2,244.155820		

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	....	449	898	1,346	1,795	2,244	2,693	3,142	3,591	4,039
1	4,488	4,937	5,386	5,835	6,284	6,732	7,181	7,630	8,079	8,528
2	8,977	9,425	9,874	10,323	10,772	11,221	11,670	12,118	12,567	13,016
3	13,465	13,914	14,363	14,811	15,260	15,709	16,158	16,607	17,056	17,504
4	17,953	18,402	18,851	19,300	19,749	20,197	20,646	21,095	21,544	21,993
5	22,442	22,890	23,339	23,788	24,237	24,686	25,135	25,583	26,032	26,481
6	26,930	27,379	27,828	28,276	28,725	29,174	29,623	30,072	30,521	30,969
7	31,418	31,867	32,316	32,765	33,214	33,662	34,111	34,560	35,009	35,458
8	35,906	36,355	36,804	37,253	37,702	38,151	38,599	39,048	39,497	39,946
9	40,395	40,844	41,292	41,741	42,190	42,639	43,088	43,537	43,985	44,434

Minute-gallons into second-feet.

Factors: 1 gallon contains 231 cubic inches; 1 cubic foot contains 1,728 cubic inches; 1 gallon per minute equals [(231 ÷ 1,728) ÷ 60] second-feet, or .002,228,009, 2 second-feet.

[In second-feet.]

1 minute-gallon	0.002,228,009	6 minute-gallons	0.013,368,055
2 minute-gallons	.004,456,018	7 minute-gallons	.015,596,064
3 minute-gallons	.006,684,028	8 minute-gallons	.017,824.074
4 minute-gallons	.008,912,037	9 minute-gallons	.020,052,083
5 minute-gallons	.011,140,046		

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	....	0.0022	0.0045	0.0067	0.0089	0.0111	0.0134	0.0156	0.0178	0.0201
1	0.0223	.0245	.0267	.0290	.0312	.0334	.0356	.0379	.0401	.0423
2	.0446	.0468	.0490	.0512	.0535	.0557	.0579	.0602	.0624	.0646
3	.0668	.0691	.0713	.0735	.0758	.0780	.0802	.0824	.0847	.0869
4	.0891	.0913	.0936	.0958	.0980	.1003	.1025	.1047	.1069	.1092
5	.1114	.1136	.1159	.1181	.1203	.1225	.1248	.1270	.1292	.1314
6	.1337	.1359	.1381	.1404	.1426	.1448	.1470	.1493	.1515	.1537
7	.1560	.1582	.1604	.1626	.1649	.1671	.1693	.1716	.1738	.1760
8	.1782	.1805	.1827	.1849	.1872	.1894	.1916	.1938	.1961	.1983
9	.2005	.2028	.2050	.2072	.2094	.2117	.2139	.2161	.2183	.2206

Meters to feet.

Meters.	Feet.	Meters.	Feet.	Meters.	Feet.
1=....................	3.2808	4=....................	13.1235	7=....................	22.9661
2=....................	6.5617	5=....................	16.4043	8=....................	26.2470
3=....................	9.8426	6=....................	19.6850	9=....................	29.5278

Feet to meters.

$$1 \text{ foot} = \frac{1}{3.2808} = 0.3048 \text{ meter.}$$

Feet.	Meters.	Feet.	Meters.	Feet.	Meters.
1=....................	0.3048	4=....................	1.2192	7=....................	2.1336
2=....................	.6096	5=....................	1.5240	8=....................	2.4384
3=....................	.9144	6=....................	1.8288	9=....................	2.7432

"Grains per U. S. gallon" to "parts per million."

1 gal.=8.3454 pounds.
1 pound=7.000 grains.
1 gal.=58,418.15 grains.

$$1 \text{ grain per gallon} = \frac{(\quad 1 \quad)}{(58{,}418.15)} (1{,}000{,}000) = 17.117{,}967 \text{ parts per million.}$$

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	....	17.1	34.2	51.4	68.5	85.6	102.7	119.8	136.9	154.1
1	171.2	188.3	205.4	222.5	239.6	256.8	273.9	291.0	308.1	325.2
2	342.4	359.5	376.6	393.7	410.8	427.9	445.1	462.2	479.3	496.4
3	513.5	530.6	547.8	564.9	582.0	599.1	616.2	633.4	650.5	667.6
4	684.7	701.8	719.0	736.1	753.2	770.3	787.4	804.5	821.7	838.8
5	855.9	873.0	890.1	907.2	924.4	941.5	958.6	975.7	992.8	1,010.0
6	1,027.1	1,044.2	1,061.3	1,078.4	1,095.5	1,112.7	1,129.8	1,146.9	1,164.0	1,181.1
7	1,198.2	1,215.4	1,232.5	1,249.6	1,266.7	1,283.8	1,301.0	1,318.1	1,335.2	1,352.3
8	1,369.4	1,386.6	1,403.7	1,420.8	1,437.9	1,455.0	1,472.1	1,489.3	1,506.4	1,523.5
9	1,540.6	1,557.7	1,574.8	1,592.0	1,609.1	1,626.2	1,643.3	1,660.4	1,677.6	1,694.7
10	1,711.8	1,728.9	1,746.0	1,763.2	1,780.3	1,797.4	1,814.5	1,831.6	1,848.7	1,865.8

Table of H 3/2 for calculating horsepower of turbines.

Head in feet.	0.0.	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	0.0000	0.0316	0.0894	0.1643	0.2530	0.3536	0.4648	0.5857	0.7155	0.8538
1	1.0000	1.1537	1.3145	1.4822	1.6565	1.8371	2.0238	2.2165	2.4150	2.6190
2	2.8284	3.0432	3.2631	3.4881	3.7181	3.9529	4.1924	4.4366	4.6853	4.9385
3	5.1962	5.4581	5.7243	5.9947	6.2693	6.5479	6.8305	7.1171	7.4076	7.7019
4	8.0000	8.3019	8.6074	8.9167	9.2295	9.5459	9.8659	10.1894	10.5163	10.8466
5	11.1803	11.5174	11.8578	12.2015	12.5485	12.8986	13.2520	13.6086	13.9682	14.3311
6	14.6969	15.0659	15.4379	15.8129	16.1909	16.5718	16.9557	17.3425	17.7322	18.1248
7	18.5203	18.9185	19.3196	19.7235	20.1302	20.5396	20.9518	21.3666	21.7842	22.2045
8	22.6274	23.0530	23.4812	23.9121	24.3455	24.7815	25.2202	25.6613	26.1050	26.5523
9	27.0000	27.4512	27.9050	28.3612	28.8199	29.2810	29.7445	30.2105	30.6789	31.1496
10	31.6228	32.0983	32.5762	33.0564	33.5390	34.0239	34.5111	35.0006	35.4924	35.9865
11	36.4829	36.9815	37.4824	37.9855	38.4908	38.9984	39.5082	40.0202	40.5343	41.0507
12	41.5692	42.0910	42.6128	43.1388	43.6648	44.1952	44.7256	45.2600	45.7944	46.3332
13	46.8720	47.4148	47.9576	48.5048	49.0520	49.6032	50.1544	50.7096	51.2648	51.8240
14	52.3832	52.9464	53.5096	54.0768	54.6440	55.2152	55.7864	56.3616	56.9368	57.5156
15	58.0944	58.6776	59.2608	59.8472	60.4336	61.0244	61.6152	62.2096	62.8040	63.4020
16	64.0000	64.6020	65.2040	65.8096	66.4152	67.0244	67.6336	68.2464	68.8592	69.4760
17	70.0928	70.7132	71.3336	71.9572	75.5808	73.2084	73.8360	74.4672	75.0984	75.7328
18	76.3672	77.0056	77.6440	78.2856	78.9272	79.5724	80.2176	80.8664	81.5152	82.1672
19	82.8192	83.4748	84.1304	84.7892	85.4480	86.1104	86.7728	87.4384	88.1040	88.7732
20	89.4424	90.1152	90.7880	91.4636	92.1392	92.8184	93.4976	94.1800	94.8624	95.5484
21	96.2344	96.9232	97.6120	98.3044	98.9968	99.6924	100.3880	101.0868	101.7856	102.4872
22	103.1883	103.8940	104.6008	105.3076	106.0160	106.7276	107.4392	108.1540	108.8688	109.5864
23	110.3040	111.0248	111.7456	112.4700	113.1944	113.9216	114.6488	115.3788	116.1088	116.8420
24	117.5752	118.3128	119.0496	119.7876	120.5272	121.2696	122.0120	122.7576	123.5032	124.2516
25	125.0000	125.7516	126.5032	127.2576	128.0120	128.7706	129.5292	130.2876	131.0480	131.8112
26	132.5744	133.3408	134.1072	134.8764	135.6456	136.4180	137.1904	137.9652	138.7400	139.5180
27	140.2960	141.0768	141.8576	142.6416	143.4256	144.2120	144.9984	145.7880	146.5776	147.3700
28	148.1624	148.9572	149.7520	150.5500	151.3480	152.1488	152.9496	153.7532	154.5568	155.3632
29	156.1696	156.9788	157.7880	158.6000	159.4120	160.2268	161.0416	161.8588	162.6760	163.4964
30	164.3168	165.1396	165.9624	166.7884	167.6144	168.4428	169.2712	170.1020	170.9328	171.7668
31	172.6008	173.4372	174.2736	175.1128	175.9520	176.7940	177.6360	178.4804	179.3248	180.1720
32	181.0192	181.8692	182.7192	183.5716	184.4240	185.2792	186.1344	186.9920	187.8496	188.7100
33	189.5704	190.4336	191.2968	192.1624	193.0280	193.8960	194.7640	195.6348	196.5056	197.3788
34	198.2520	199.1460	200.0400	200.9008	201.7616	202.6424	203.5232	204.4068	205.2904	206.1764
35	207.0624	207.9512	208.8400	209.7312	210.6224	211.5204	212.4184	213.3104	214.2024	215.1012
36	216.0000	216.9012	217.8024	218.7060	219.6096	220.5760	221.4224	222.3312	223.2400	224.1512
37	225.0624	225.9760	226.8896	227.8056	228.7216	299.6404	230.5592	231.4800	232.4008	233.3244
38	234.2480	235.1736	236.0992	237.0276	237.9560	238.8868	239.8176	240.7508	241.6840	242.6196
39	243.5552	244.4932	245.4312	246.3712	247.3112	248.2540	249.1968	250.1420	251.0872	252.0348
40	252.9824	253.9320	254.8816	255.8340	256.7864	257.7412	258.6960	259.6528	260.6096	261.5688
41	262.5280	263.4896	264.4512	265.4152	266.3792	267.3456	268.3120	269.2804	270.2488	271.2200
42	272.1912	273.1644	274.1376	275.1132	276.0888	277.0672	278.0456	279.6252	280.0048	280.9872
43	281.9696	282.9544	283.9392	284.9264	285.9136	286.9028	287.8920	288.8836	289.8752	290.8692
44	291.8632	292.8597	293.8552	294.8536	295.8520	296.8528	297.8536	298.8564	299.8592	300.8640
45	301.8688	302.8764	303.8840	304.8936	305.9032	306.9148	307.9264	308.9404	309.9544	310.9708
46	311.9872	313.0056	314.0240	315.0448	316.0656	317.0877	318.1112	319.0556	320.0000	321.1080
47	322.2160	323.2452	324.2744	325.3060	326.3376	327.3716	328.4056	329.4416	330.4776	331.5156
48	332.5536	333.5927	334.6333	335.4753	336.7188	337.7588	338.8051	339.8529	340.8972	341.9479
49	343.0000	344.0486	345.0986	346.1500	347.2079	348.2622	349.3179	350.3750	351.4336	352.4886
50	353.5500	354.6128	355.6720	356.7376	357.7996	358.8681	359.9329	360.9992	362.0719	363.1409

Table of H 3/2 for calculating horsepower of turbines.

Head in feet.	0.0.	.1	.2	.3	.4	.5	.6	.7	.8	.9
51	364.2114	365.2832	366.3564	367.4311	368.5020	369.5794	370.6582	371.7333	372.8149	373.8927
52	374.9772	376.0578	377.1397	378.2331	379.3078	380.3940	381.4815	382.5703	383.6606	384.7522
53	385.8453	386.9343	388.0301	389.1219	390.2205	391.3150	392.4163	393.5136	394.6122	395.7122
54	396.8136	397.9163	399.0204	400.1258	401.2326	402 3408	403.4448	404.5557	405.6679	406.7759
55	407.8855	409.0017	410.1139	411.2273	412.3477	413.4639	414.5814	415.7002	416.8204	417.9419
56	419.0648	420.1833	421.3089	422.4257	423.5583	424.6879	425.8131	426.9453	428.0732	429.2080
57	430.3386	431.4704	432.6036	433.7380	434.8738	436.0110	437.1494	438.2892	439.4302	440.5726
58	441.7106	442.8556	443.9961	445.1438	446.2869	447.4372	448.5830	449.7300	450.8842	452.0359
59	454.0849	455.3271	455.4907	456.6455	457.8017	458.9592	460.1179	461.2720	462.4334	463.5960
60	464.7540	465.9192	467.0797	468.2475	469.4106	470.5750	471.7467	472.9137	474.0819	475.2514
61	476.4222	477.3942	478.7676	479.9422	481.1181	482.2891	483.4676	484.6473	485.8222	487.0044
62	488.1880	489.3666	490.5465	491.7339	492.9163	494.1000	495.2912	496.4774	497.6648	498.8536
63	500.0436	501.2348	502.4273	503.6211	504.8161	506.0061	507.2036	508.4024	509.5961	510.7974
64	512.0000	513.1974	514.3960	515.6024	516.8035	518.0059	519.2160	520.4209	521.6270	522.8344
65	524.0430	525.2528	526.4639	527.6762	528.8898	530.1046	531.3120	532.5313	533.7498	534.9630
66	536.1840	537.2996	538.6230	539.8411	541.0670	542.2875	543.5092	544.7389	545.9630	547.1884
67	548.4151	549.6429	550.8720	552.1022	553.3337	554.5665	555.6179	557.0356	558.2652	559.5027
68	560.7416	561.9748	563.2160	564.4516	565.6953	566.9334	568.1795	569.4199	570.6616	571.9113
69	573.1554	574.4006	575.6473	576.8947	578.1436	579.3937	580.6449	581.8974	583.1510	584.4059
70	585.6620	586.9122	588.1707	589.4303	590.6841	591.9462	593.2023	594.4668	595.7253	596.9921
71	598.2531	599.5152	600.7856	602.0500	603.3157	604.5825	605.8505	607.1197	608.3901	609.6616
72	610.9344	612.2083	613.4340	614.7596	616.0371	617.3085	618.5883	619.8692	621.0841	622.4274
73	623.7120	624.9903	626.2699	627.5579	628.8398	630.1302	631.4144	632.6997	633.9862	635.2813
74	636.5702	637.8602	639.1513	640.4437	641.7372	643.0318	644.3276	645.6246	646.9152	648.2145
75	649.5150	650.8166	652.1118	653.4157	654.7208	656.0195	657.3268	658.6278	659.9375	661.2408
76	662.5452	663.8583	665.1650	666.4728	667.7894	669.0996	670.4108	671.7131	673.0368	674.3514
77	675.6673	676.9842	677.2043	679.6216	680.9419	682.2635	683.5784	684.9021	686.2271	687.5454
78	688.8726	690.2009	691.5226	692.8532	694.1771	695.5100	696.8361	698.1713	699.4997	700.8292
79	702.1599	703.4995	704.8324	706.1665	707.5016	708.8379	710.1752	711.5137	712.8534	714.1941
80	715.5360	716.8789	718.2230	719.5683	720.9146	722.2540	723.6026	724.9523	726.2950	727.6496
81	729.0000	730.3460	731.7613	733.0495	734.3989	735.7575	737.1091	738.4699	739.8237	741.1876
82	742.5346	743.8998	745.2580	746.6173	747.9776	749.3392	750.7018	752.0655	753.4303	754.7962
83	756.1632	757.5312	758.9004	760.2624	761.6338	763.0063	764.3798	765.7461	767.1219	768.4904
84	769.8684	771.2474	772.6192	774.0004	775.3743	776.7493	778.1338	779.5110	780.8892	782.2770
85	783.6575	785.0389	786.4215	787.8052	789.1984	790.5843	791.9712	793.3591	794.7482	796.1383
86	797.5296	798.9219	800.3066	801.7011	803.0966	804.4932	805.8909	807.2810	808.6808	810.0833
87	811.4751	812.8781	814.2736	815.6788	817.0763	818.4837	819.8834	821.2929	822.6947	824.1064
88	825.5704	826.9154	828.3214	829.7374	831.1456	832.5549	833.9652	835.3766	836.7890	838.2025
89	839.6171	841.0327	842.4494	843.8671	845.2859	846.7058	848.1267	849.5487	850.9627	852.3868
90	853.8120	855.2382	856.6564	858.0847	859.5051	860.9355	862.3670	863.7905	865.2241	866.6496
91	868.0763	869.5130	870.9417	872.3806	873.8114	875.2432	876.6761	878.1192	879.5541	880.9901
92	882.4272	883.8652	885.3044	886.7445	888.1857	889.6280	891.0712	892.5156	893.9609	895.4073
93	896.8548	898.3032	899.7528	901.1946	902.6456	904.0982	905.5519	906.9972	908.4530	909.9097
94	911.3582	912.8170	914.2675	915.7284	917.1809	918.6439	920.0985	921.5541	923.0202	924.4778
95	925.9365	927.4056	928.8664	930.3281	931.7908	933.2642	934.7290	936.1948	937.6616	939.1295
96	940.5984	942.0683	943.5392	945.0111	946.4841	947.9581	949.4331	950.9091	952.3764	953.8545
97	955.3336	956.8136	958.2948	959.7672	961.2503	962.7345	964.2099	965.6961	967.1735	968.6617
98	970.1412	971.6314	973.1129	974.6051	976.0886	977.5829	979.0684	980.5548	982.0522	983.5407
99	985.0302	986.5206	988.0220	989.5145	991.0080	992.5025	993.9980	995.4945	996.9920	998.4905
100	1,000.0000	....	....	....	....	....	....	....	....	....

Table of three-halves powers.

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	
.00	0.0000	1.0000	2.8284	5.1962	8.0000	11.1803	14.6969	18.5203	22.6274	27.0000	31.6228	36.4829	.00
.01	0.0010	1.0150	2.8497	5.2222	8.0300	11.2139	14.7337	18.5600	22.6699	27.0450	31.6702	36.5326	.01
.02	0.0028	1.0302	2.8710	5.2482	8.0601	11.2475	14.7705	18.5997	22.7123	27.0890	31.7177	36.5824	.02
.03	0.0052	1.0453	2.8923	5.2743	8.0902	11.2811	14.8073	18.6394	22.7548	27.1351	31.7652	36.6322	.03
.04	0.0080	1.0606	2.9137	5.3004	8.1203	11.3148	14.8442	18.6792	22.7973	27.1802	31.8127	36.6820	.04
.05	0.0112	1.0759	2.9352	5.3266	8.1505	11.3485	14.8810	18.7190	22.8399	27.2253	31.8602	36.7319	.05
.06	0.0147	1.0913	2.9567	5.3528	8.1807	11.3822	14.9179	18.7589	22.8825	27.2705	31.9078	36.7818	.06
.07	0.0185	1.1068	2.9782	5.3791	8.2109	11.4160	14.9549	18.7988	22.9251	27.3156	31.9554	36.8317	.07
.08	0.0226	1.1224	2.9998	5.4054	8.2412	11.4497	14.9919	18.8387	22.9677	27.3608	32.0030	36.8816	.08
.09	0.0270	1.1380	3.0215	5.4317	8.2715	11.4836	15.0289	18.8786	23.0103	27.4060	32.0506	36.9315	.09
.10	0.0316	1.1537	3.0432	5.4581	8.3019	11.5174	15.0659	18.9185	23.0530	27.4512	32.0983	36.9815	.10
.11	0.0365	1.1695	3.0650	5.4845	8.3323	11.5513	15.1030	18.9585	23.0957	27.4965	32.1460	37.0315	.11
.12	0.0416	1.1853	3.0868	5.5110	8.3627	11.5852	15.1400	18.9985	23.1384	27.5418	32.1937	37.0815	.12
.13	0.0469	1.2012	3.1086	5.5375	8.3932	11.6192	15.1772	19.0386	23.1812	27.5871	32.2414	37.1315	.13
.14	0.0524	1.2172	3.1306	5.5641	8.4237	11.6532	15.2143	19.0786	23.2240	27.6324	32.2892	37.1816	.14
.15	0.0581	1.2332	3.1525	5.5907	8.4542	11.6872	15.2515	19.1187	23.2668	27.6778	32.3370	37.2317	.15
.16	0.0640	1.2494	3.1745	5.6173	8.4848	11.7213	15.2887	19.1589	23.3096	27.7232	32.3848	37.2817	.16
.17	0.0701	1.2656	3.1966	5.6440	8.5154	11.7554	15.3260	19.1990	23.3525	27.7686	32.4326	37.3319	.17
.18	0.0764	1.2818	3.2187	5.6708	8.5460	11.7895	15.3632	19.2392	23.3954	27.8140	32.4804	37.3820	.18
.19	0.0828	1.2981	3.2409	5.6975	8.5767	11.8236	15.4005	19.2794	23.4383	27.8595	32.5283	37.4322	.19
.20	0.0894	1.3145	3.2631	5.7243	8.6074	11.8578	15.4379	19.3196	23.4812	27.9050	32.5762	37.4824	.20
.21	0.0962	1.3310	3.2854	5.7512	8.6382	11.8920	15.4752	19.3599	23.5242	27.9514	32.6241	37.5326	.21
.22	0.1032	1.3475	3.3077	5.7781	8.6690	11.9263	15.5126	19.4002	23.5672	27.9960	32.6720	37.5828	.22
.23	0.1103	1.3641	3.3301	5.8050	8.6998	11.9606	15.5501	19.4405	23.6102	28.0416	32.7200	37.6331	.23
.24	0.1176	1.3808	3.3525	5.8320	8.7307	11.9949	15.5866	19.4808	23.6533	28.0872	32.7680	37.6833	.24
.25	0.1250	1.3975	3.3750	5.8590	8.7616	12.0293	15.6250	19.5212	23.6963	28.1328	32.8160	37.7336	.25
.26	0.1326	1.4144	3.3975	5.8861	8.7925	12.0636	15.6616	19.5576	23.7394	28.1784	32.8640	37.7840	.26
.27	0.1403	1.4312	3.4201	5.9132	8.8235	12.0981	15.7001	19.6021	23.7825	28.2241	32.9121	37.8343	.27
.28	0.1482	1.4482	3.4427	5.9403	8.8545	12.1325	15.7376	19.6425	23.8257	28.2698	32.9600	37.8847	.28
.29	0.1562	1.4652	3.4654	5.9675	8.8856	12.1670	15.7752	19.6830	23.8689	28.3155	33.0083	37.9351	.29
.30	0.1643	1.4822	3.4881	5.9947	8.9167	12.2015	15.8129	19.7235	23.9121	28.3612	33.0564	37.9855	.30
.31	0.1726	1.4994	3.5109	6.0220	8.9478	12.2361	15.8505	19.7641	23.9553	28.4069	33.1046	38.0359	.31
.32	0.1810	1.5166	3.5337	6.0493	8.9790	12.2706	15.8882	19.8046	23.9986	28.4527	33.1527	38.0864	.32
.33	0.1896	1.5338	3.5566	6.0767	9.0102	12.3053	15.9260	19.8452	24.0418	28.4985	33.2009	38.1369	.33
.34	0.1983	1.5512	3.5795	6.1041	9.0414	12.3399	15.9637	19.8858	24.0851	28.5444	33.2492	38.1874	.34
.35	0.2071	1.5686	3.6025	6.1315	9.0726	12.3746	16.0015	19.9265	24.1285	23.5902	33.2974	38.2379	.35
.36	0.2160	1.5860	3.6255	6.1590	9.1040	12.4093	16.0393	19.9672	24.1718	28.6361	33.3457	38.2884	.36
.37	0.2251	1.6035	3.6486	6.1865	9.1353	12.4440	16.0772	20.0079	24.2152	28.6820	33.3940	38.3390	.37
.38	0.2342	1.6211	3.6717	6.2141	9.1667	12.4788	16.1150	20.0486	24.2586	28.7279	33.4423	38.3896	.38
.39	0.2436	1.6388	3.6949	6.2417	9.1981	12.5136	16.1529	20.0894	24.3021	28.7739	33.4906	38.4402	.39
.40	0.2530	1.6565	3.7181	6.2693	9.2295	12.5485	16.1909	20.1302	24.3455	28.8199	33.5390	38.4908	.40
.41	0.2625	1.6743	3.7413	6.2970	9.2610	12.5833	16.2288	20.1710	24.3890	28.1659	33.5874	38.5415	.41
.42	0.2722	1.6921	3.7646	6.3247	9.2925	12.6182	16.2668	20.2118	24.4325	28.9119	33.6358	38.5922	.42
.43	0.2820	1.7100	3.7880	6.3525	9.3241	12.6532	16.3048	20.2527	24.4761	28.9579	33.6842	38.6429	.43
.44	0.2919	1.7280	3.8114	6.3803	9.3557	12.6882	16.3429	20.2936	24.5196	29.0040	33.7327	38.6936	.44
.45	0.3019	1.7460	3.8349	6.4081	9.3873	12.7232	16.3810	20.3345	24.5632	29.0501	33.7811	38.7443	.45
.46	0.3120	1.7641	3.8584	6.4360	9.4189	12.7582	16.4191	20.3755	24.6068	29.0962	33.8297	38.7951	.46
.47	0.3222	1.7823	3.8819	6.4639	9.4506	12.7933	16.4572	20.4165	24.6505	29.1424	33.8782	38.8459	.47
.48	0.3325	1.8005	3.9055	6.4919	9.4824	12.8284	16.4954	20.4575	24.6941	29.1885	33.9267	38.8967	.48
.49	0.3430	1.8188	3.9292	6.5199	9.5141	12.8635	16.5336	20.4985	24.7378	29.2347	33.9753	38.9475	.49
.50	0.3536	1.8371	3.9529	6.5479	9.5459	12.8986	16.5718	20.5396	24.7815	29.2810	34.0239	38.9984	.50

Table of three-halves powers—Continued.

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	
.51	0.3642	1.8555	3.9766	6.5760	9.5778	12.9338	16.6101	20.5807	24.8253	29.3272	34.0725	39.0493	.51
.52	0.3750	1.8740	4.0004	6.6041	9.6097	12.9691	16.6484	20.6218	24.8691	29.3735	34.1211	39.1002	.52
.53	0.3858	1.8925	4.0242	6.6323	9.6416	13.0043	16.6867	20.6630	24.9129	29.4198	34.1698	39.1511	.53
.54	0.3968	1.9111	4.0481	6.6605	9.6735	13.0396	16.7250	20.7041	24.9567	29.4661	34.2185	39.2020	.54
.55	0.4079	1.9297	4.2520	6.6887	9.7055	13.0749	16.7634	20.7453	25.0005	29.5124	34.2672	39.2530	.55
.56	0.4191	1.9484	4.0960	6.7170	9.7375	13.1103	16.8018	20.7866	25.0444	29.5588	34.3159	39.3040	.56
.57	0.4303	1.9672	4.1200	6.7453	9.7695	13.1457	16.8402	20.8278	25.0883	29.6052	34.3647	39.3550	.57
.58	0.4417	1.9860	4.1441	6.7737	9.8016	13.1811	16.8787	20.8691	25.1322	29.6516	34.4135	39.4060	.58
.59	0.4532	2.0049	4.1682	6.8021	9.8337	13.2165	16.9172	20.9104	25.1762	29.6980	34.4623	39.4571	.59
.60	0.4648	2.0238	4.1924	6.8305	9.8659	13.2520	16.9557	20.9518	25.2202	29.7445	34.5111	39.5082	.60
.61	0.4764	2.0429	4.2166	6.8590	9.8981	13.2875	16.9943	20.9931	25.2642	29.7910	34.5599	39.5593	.61
.62	0.4882	2.0619	4.2408	6.8875	9.9303	13.3231	17.0328	21.0345	25.3082	29.8375	34.6088	39.6104	.62
.63	0.5000	2.0810	4.2651	6.9161	9.9626	13.3587	17.0714	21.0759	25.3522	29.8841	34.6577	39.6615	.63
.64	0.5120	2.1002	4.2895	6.9447	9.9949	13.3943	17.1101	21.1174	25.3963	29.9306	34.7066	39.7127	.64
.65	0.5240	2.1195	4.3139	6.9733	10.0272	13.4299	17.1488	21.1589	25.4404	29.9772	34.7557	39.7639	.65
.66	0.5362	2.1388	4.3383	7.0020	10.0596	13.4166	17.1874	21.2004	25.4845	30.0238	34.8045	39.8151	.66
.67	0.5484	2.1581	4.3628	7.0307	10.5920	13.5013	17.2172	21.2419	25.5287	30.0704	34.8535	39.8663	.67
.68	0.5607	2.1775	4.3874	7.0595	10.1244	13.5370	17.2649	21.2834	25.5729	30.1171	34.9025	39.9176	.68
.69	0.5732	2.1970	4.4119	7.0883	10.1569	13.5728	17.3037	21.3250	25.6171	30.1638	34.9516	39 9689	.69
.70	0.5857	2.2165	4.4366	7.1171	10.1894	13.6086	17.3425	21.3666	25.6613	30.2105	35.0006	40.0202	.70
.71	0.5983	2.2361	4.4612	7.1460	10.2214	13.6444	17.3814	21.4083	25.7056	30.2572	35.0497	40.0715	.71
.72	0.6109	2.2558	4.4859	7.1749	10.2545	13.6803	17.4202	21.4499	25.7499	30.3040	35.0988	40.1228	.72
.73	0.6237	2.2755	4.5107	7.2038	10.2871	13.7161	17.4591	21.4916	25.7942	30.3507	35.1479	40.1742	.73
.74	0.6366	2.2952	4.5355	7.2328	10.3197	13.7521	17.4981	21.5333	25.8395	30.3975	35.1971	40.2256	.74
.75	0.6495	2.3150	4.5604	7.2618	10.3524	13.7880	17.5370	21.5751	25.8828	30.4444	35.2462	40.2770	.75
.76	0.6626	2.3349	4.5853	7.2909	10.3851	13.8240	17.5760	21.6169	25.9272	30.4912	35.2954	40.3284	.76
.77	0.6757	2.3548	4.6102	7.3200	10.4178	13.8600	17.6150	21.6587	25.9716	30.5381	35.3446	40.3798	.77
.78	0.6889	2.3748	.6352	7.3492	10.4506	13.8961	17.6541	21.7005	26.0161	30.5850	35.3939	40.4313	.78
.79	0.7022	2.3949	4.6602	7.3783	10.4834	13.9321	17.6931	21.7423	26.0605	30.6319	35.4431	40.4828	.79
.80	0.7155	2.4150	4.6853	7.4076	10.5163	13.9682	17.7322	21.7842	26.1050	30.6789	35.4924	40.5343	.80
.81	0.7290	2.4351	4.7104	7.4368	10.5492	14.0044	17.7714	21.8261	26.1495	30.7258	35.5417	40.5859	.81
.82	0.7425	2.4553	4.7356	7.4661	10.5812	14.0406	17.8105	21.8681	26.1941	30.7728	35.5911	40.6374	.82
.83	0.7562	2.4756	4.7608	7.4955	10.6150	14.0768	17.8507	21.9100	26.2386	30.8198	35.6404	40.6890	.83
.84	0.7699	2.4959	4.7861	7.5248	10.6480	14.1130	17.8889	21.9520	26.2832	30.8669	35.6898	40.7406	.84
.85	0.7837	2.5163	4.8114	7.5542	10.6810	14.1493	17.9282	21.9940	26.3278	30.9139	35.7392	40.7922	.85
.86	0.7975	2.5367	4.8367	7.5837	10.7141	14.1856	17.9674	22.0361	26.3725	30.9610	35.7886	40.8439	.86
.87	0.8115	2.5572	4.8621	7.6132	10.7472	14.2219	18.0067	22.0781	26.4171	31.0081	35.8380	40.8955	.87
.88	0.8255	2.5777	4.8875	7.6427	10.7803	14.2582	18.0461	22.1202	26.4618	31.0553	35.8875	40.9472	.88
.89	0.8396	2.5983	4.9130	7.6723	10.8134	14.2946	18.0854	22.1623	26.5065	31.1024	35.9370	40.9989	.89
.90	0.8538	2.6190	4.9385	7.7019	10.8466	14.3311	18.1248	22.2045	26.5523	31.1496	35.9865	41.0507	.90
.91	0.8681	2.6397	4.9641	7.7315	10.8798	14.3675	18.1642	22.2467	26.5960	31.1968	36.0360	41.1024	.91
.92	0.8824	2.6604	4.9897	7.7702	10.9131	14.4040	18.2037	22.2889	26.6408	31.2441	36.0856	41.1542	.92
.93	0.8969	2.6812	5.0154	7.7909	10.9464	14.4405	18.2432	22.3311	26.6856	31.2913	36.1352	41.2060	.93
.94	0.9114	2.7021	5.0411	7.8207	10.9797	14.4770	18.2827	22.3733	26.7305	31.3386	36.1848	41.2578	.94
.95	0.9259	2.7230	5.0668	7.8505	11.0131	14.5136	18.3222	22.4156	26.7753	31.3850	36.2344	41.3097	.95
.96	0.9406	2.7440	5.0926	7.8803	11.0464	14.5502	18.3617	22.4579	26.8202	31.4332	36.2841	41.3615	.96
.97	0.9553	2.7650	5.1184	7.9102	11.0799	14.5869	18.4013	22.5003	26.8651	31.4806	36.3337	41.4134	.97
.98	0.9702	2.7861	5.1443	7.9401	11.1133	14.6235	18.4409	22.5426	26.9100	31.5280	36.3834	41.4653	.98
.99	0.9850	2.8072	5.1702	7.9700	11.1468	14.6602	18.4806	22.5850	26.9550	31.5754	36.4331	41.5173	.99
1.00	1.0000	2.8284	5.1962	8.0000	11.1803	14.6969	18.5203	22.6274	27.0000	31.6228	36.4829	41.5692	1.00

CONVENIENT EQUIVALENTS.

1 second-foot equals 50 California miner's inches.
1 second-foot equals 38.4 Colorado miner's inches.
1 second-foot equals 40 Arizona miner's inches.
1 second-foot equals 7.48 United States gallons per second.
1 second-foot equals 6.23 British imperial gallons.
1 second-foot for one day equals 1.9835 acre-feet.
1 second-foot for one day equals 646,272 United States gallons.
1 second-foot for one year equals 0.000214 cubic mile.
1 second-foot for one year covers 1 square mile 1.131 feet deep.
1 second-foot equals 449.9 gallons per minute.
1 second-foot equals about one acre-inch per hour.
1 cubic foot of water weighs 62.47 pounds.
100 California miner's inch equals 2 second-feet.
100 California miner's inches equals 15 United States gallons per second.
100 California miner's inches equals 77 Colorado miner's inches.
100 California miner's inches for one day equals 4 acre-feet.
100 Colorado miner's inches equals 2.60 square feet.
100 Colorado miner's inches equals 19.5 United States gallons per second.
100 Colorado miner's inches equals 130 California miner's inches.
100 Colorado miner's inches for one day equals 5.2 acre-feet.
100 United States gallons per minute equals .223 second-foot.
100 United States gallons per minute for one day equals 44 acre-feet.
1 million United States gallons per day equals 1.55 second-feet.
1 million United States gallons equals 3.07 acre-feet.
1 million cubic feet equals 22.95 acre-feet.
1 acre-foot equals 325,850 gallons.
A layer 1 inch deep on one square mile equals 2,323,200 cubic feet.
A flow of 1 second-foot in one year equals 31,536,000 cubic feet.
1 inch deep on 1 square mile equals 0.0737 second-foot per year.
10 inches deep on 1 square mile equals 0.7367 second-foot per year.
A flow of 1 second-foot per year covers 1 square inch 13.589.
1 cubic mile equals 147,198,000,000 cubic feet.
1 cubic mile equals 4,667 second-feet.
1 second-foot per year equals 31,536,000 cubic feet.
1 second-foot per year equals 0.000214 cubic mile.
1 foot per second equals 1.077 kilometers per hour.
1 foot per second equals 0.68 mile per hour.
1 inch equals 2.54 centimeters.
1 foot equals 0.3048 meter.
1 yard equals 0.9144 meters.
1 mile equals 1.60935 kilometers.
1 square yard equals 0.836 square meter.
1 acre equals 0.4047 hectare.
1 square mile equals 259 hectares.
1 square mile equals 2.59 square kilometers.
1 cubic foot equals 0.0283 cubic meter.
1 cubic yard equals 0.7646 cubic meter.
1 gallon equals 3.7854 liters.
1 pound equals 0.4536 kilogram.
1 atmosphere equals about 15 pounds per square inch, 1 ton per square foot, 1 kilo per square centimeter.
Acceleration of gravity equals 32.16 feet per second every second.

1 acre equals 209 feet square, nearly.
1 acre equals 43,560 square feet, equals 4,840 square yards.
1 mile equals 1,760 yards, equals 5,280 feet, equals 63,360 inches.
1 cubic foot equals 7.48 gallons, equals 0.804 bushel.
1 gallon equals 8.34 pounds of water.
1 gallon equals 231 cubic inches (liquid measure).
1 avoirdupois pound equals 7,000 grains.
1 troy pound equals 5,760 grams.
1 meter equals 39.37 inches. Log. 1.5951654.
1 meter equals 3.28083 feet. Log. 0.5159842.
1 meter equals 1.093611 yards. Log. 0.0388629.
1 meter equals 0.00062137 mile. Log. 6.7933495.
1 kilometer equals 3,281 feet, equals $\frac{5}{8}$ mile, nearly.
1 square meter equals 10,764 square feet, equals 1.196 square yard.
1 hectare equals 2.471 acres.
1 cubic meter equals 35.314 cubic feet, equals 1.308 cubic yards.
1 liter equals 1.0567 quarts.
1 gram equals 15.43 grains.
1 kilogram equals 2.2046 pounds.
1 tonneau equals 2,204.6 pounds.
1 cubic meter per minute equals 0.5886 second-foot.
1 horsepower equals 550 foot-pounds per second.
1 horsepower equals 76 kilogrameters per second.
1 horsepower equals 746 watts.
1 horsepower equals 1 second-foot of water falling 8.8 feet.
1 second-foot falling 10 feet equals 1.135 horsepower.
$1\frac{1}{3}$ horsepowers equals about 1 kilowatt.

To calculate water power quickly: $\frac{\text{Sec.-ft. x fall in feet.}}{11}=$ Net horsepower on water wheel, realizing 80 per cent of the theoretical power.

Quick formula for computing discharges over weirs: Cubic feet per minute equals $0.4025 \; l\sqrt{h^3}$; l=length of weir in inches; h=head in inches flowing over weir, measured from surface of still water.

To change miles to inches on map:

Scale 1:125000, 1 mile = 0.50688 inches. Log. = 9.7049052.
Scale 1:90000, 1 mile = 0.70400 inches. Log. = 9.8475727.
Scale 1:62500, 1 mile = 1.01376 inches. Log. = 0.0059352.
Scale 1:45000, 1 mile = 1.40800 inches. Log. = 0.1486027.

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O

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Author.

Murphy, Edward C[harles].

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no. 94. Murphy, E. C. Hydrographic manual of the U. S. Geological survey, by E. C. Murphy, J. C. Hoyt, and G. B. Hollister. 1904.

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